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IDENTIFICATION OF PHENOLOGICAL STAGES AND VEGETATIVE TYPES FOR LAND USE CLASSIFICATION

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16. Abstract

Project objectives were to map vegetation types and observe phenological changes in vegetation. Phenological events could not be monitored due to the infrequency of coverage during the growing season and cloud-free scenes of the test areas. Vegetation types were mapped at accuracies of 66%-99%+ by automated processing of multispectral scanner (MSS) digital data for the Homer, Palmer, Petersville and Bonanza Creek Forest areas. Map scales ranged from approximately 1:18,800 to 1:500,000. Relating ground truth directly to digital data, refining MSS signatures and color digital printing were three essential techniques. Statistically analyzing MSS signatures to determine adequate training set sizes and for signature refinement greatly improved the validity of automated classification. MSS signature extrapolation proved unsuccessful for distances as great as 100 miles. Costs of false-color and color-coded thematic maps from digital data ranged between \$2.20 and \$2.60 per mi^2. Once analytical techniques were established, data handling via the U.S. mail was the most serious hindrance.

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PREFACE

Project objectives were to map vegetation types and observe phenological changes of vegetation from ERTS data, thus establishing reliable criteria for land use planning in Alaska. The scope of this work entailed: selecting data format that would yield the most useful information; correlating findings from ERTS with ground truth information; extracting, analyzing and refining multispectral scanner (MSS) signatures; establishing analytical techniques; and producing useful "hard copy" products.

ERTS data was successfully used to produce vegetation maps in Alaska. Although visual products were useful in mapping vegetation, far more accurate and highly detailed information was obtained through automated processing of MSS digital data. Vegetation was economically mapped at various scales ranging from 1:18,000 to 1:500,000. Costs for producing false color and color-coded digital thematic maps averaged $2.50 per square mile. These products are of significant value to Alaskan users as such quality data is lacking for most of the state. The project was unable to monitor phenological events due to: infrequency of coverage during the growing season and prevalent cloudy conditions during critical periods.

The greatest deficiency of ERTS lies in the data handling system; the data for an ERTS scene are collected during a 28-second period yet it may take half a year for the processed data to reach the hands of the users. A significant improvement for the Alaska system would be to acquire sufficient equipment to produce full color "hard copies" of processed computer compatible tape (CCT) data.

Investigators need to take a more active part in narrowing the gap between research and application by promoting the use of ERTS to potential users. Potential Alaska users have been reluctant to apply ERTS-1 data in solving land use and vegetation resource inventory problems.

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INTRODUCTION

Alaska's vastness is almost incomprehensible to people who have not travelled its length and breadth. Figure 1 is an illustration of the relative size of Alaska and the counterminous states. The shape of the state with its panhandle extending to the southeast over 500 miles and the Aleutian Chain extending westward into the Pacific over 1,000 miles complicates communication, transportation, and resource management problems for Alaska.

Currently Alaska is undergoing radical changes in its land ownership patterns (Figure 2). The once all federal territory, upon becoming the 49th state inherited the privilege of selecting lands for state ownership. Even more recently the Native Land Claims Settlement Act permitted the several Alaskan native corporations to choose lands for their private ownerships.

Developing Alaska petroleum reserves in the Arctic at a time when the consuming public was facing the dilemma of concern for environmental issues and oil shortages has also focused considerable attention on Alaskan land resources.

The Joint Federal-State Land Use Planning Commission for Alaska was organized to help the various interest groups acquire the needed information to insure wise use of the land resources in the state.

The demands for vegetation and other resource data associated with the aforementioned events has been inadequately served because the state of Alaska is largely uninventoried. Furthermore, the time-frame of such demands precludes acquiring such data by conventional means. Thus, satellite sensing appeared to have great promise for meeting critical vegetation resource inventory needs in Alaska (Branton and Mitchell, 1972).

This project was developed to apply ERTS-1 sensing technology to the mapping of natural vegetation types and to the observing of "green wave" phenomenon (vegetation phenology). Three Alaska test areas were selected in southcentral Alaska: the Kenai Peninsula, the Matanuska Valley and the Susitna Valley. Both of the objectives related directly to identifying and locating lands suitable for agricultural development.

During the development of the program it became obvious that in order to accurately measure phenological changes, frequent coverage was needed. Periodic cloud cover interfered seriously with the phenological observations so that objective was abandoned (see appendix A). Spectral signatures did differ with times of the year; however, we could not determine if atmospheric conditions and/or seasonal changes in vegetation were causing those differences.

In mapping vegetation types from aircraft imagery we discovered there was inconsistency among interpreters using visual methods. This resulted primarily from having to decide where to draw type lines. That is a subjective process and can be "correct" at several locations along continuum gradients. Sharp ecotones presented no particular problem except where areas had to be mapped as complexes because types were intermixed.

We reasoned that such mapping inconsistencies could only reduce the reliability of ERTS-acquired data. Upon considering the number of individuals needed to visually interpret and manually map just the vegetation for Alaska and the probable mass of data being secured by ERTS-1 on the world-wide scale, it appeared that computer analysis was the only practical approach. Therefore, the emphasis of this project has been to rely on controlled automated processing to handle the bulk of the data. Manual interpretation was used only in locating and defining training sets and refining MSS (multispectral scanner) signatures. We recognized certain misclassifications by the computer, and in most instances those were quite obvious; however, such errors could be corrected before publishing final versions of maps.

Chronology Approach

Although the project was initiated in July of 1972 our first efforts to analyze ERTS imagery were delayed until early winter 1972 when we received the first clear imagery from two of our test areas (the Matanuska Valley scene 1049-20505 and Susitna Valley scene 1033-21020). Preliminary attempts at visual interpretation were by the color additive process using the 3M color key overlays. Although certain patterns in the vegetation could be recognized, satisfactory maps at scales large enough to meet our objectives could not be constructed.

The next attempt to analyze imagery was to use density slicing. Bands 6 and 7 proved to be the most easily sliced; however, there were problems. First, density slicing could be applied to only one MSS band at a time, and that incorporated severe errors in ecotone delineations because all ecotones in the natural vegetation did not correspond to tonal separation in the imagery (i.e. density boundaries). For example, the boundary (ecotone) between a grassland-shrub-type vegetation and the mixed forest in the vicinity of Goose Bay along Cook Inlet appeared only in band 5. However, the ecotones between the mixed forest and either deciduous or coniferous forest types were obscured in band 5 and visible only in band 7.

By using the color additive viewer and bands 4, 5 and 7 we began to recognize a limited, but relatively useful amount of association between colors and vegetation types. Either projecting 70 mm imagery on the color additive viewer or photographically enlarging the imagery through color printing made little difference as far as resolution was concerned. Relating the ERTS data to specific ground truth was a serious problem. Natural vegetation types were usually intermixed and finding sufficiently large homogeneous training sets in our test areas for associating colors with vegetation proved difficult. Furthermore, once these color-vegetation associations were determined in training sets we could never be sure that human judgement was consistent for portions of the ERTS scene some distance from the training set. Thus, interpreting vegetation types in unfamiliar areas was highly subjective and believed unreliable.

It was obvious as more than one of us applied this visual interpretation process that the number of map versions resulting was directly related to the number of interpreters. With such variations, map users would soon learn to place little confidence in such maps.

In order to incorporate interpretation consistency into maps prepared from ERTS data a more precise and less subjective method was needed. Thus, computer processing of digital data was selected, since once trained, the computer would consistently recognize MSS signatures. Furthermore, the computer could work at the maximum resolution level, an impossibility for human interpretation because of the large mass of data.

Our first attempts with computer analysis were with portions of the 1049-20505 scene. Computer printer-plot listings were requested for each MSS band. These listings of intensities were then examined and MSS signatures for various vegetation types were derived. The most difficult problem was locating geographical points on the printer plots. Water bodies could be most easily recognized because they had the lowest intensities in band 7. By constructing transparent overlays which could be registered on each band's printer plot, picels representing spectral reflectance intensities were identified in one band, marked on the overlay and identified relatively quickly on the other bands. However, we were still facing the problem of relating ground truth locations to areas on the printer plots where bodies of water were scarce. To further confuse us, the vertical and horizontal scales of the printer plots were not equal, and matching printer plots to air photos (ground truth) was impossible without specialized equipment or further computer processing.

To overcome the above problems, a Bausch and Lomb Zoom Transfer Scope (ZTS) was purchased jointly by this Institute and the Joint Federal-State Land Use Planning Commission with non-NASA funds. That instrument permitted air photos to be optically superimposed on the printer plots. Thus for the first time (September 1973) since initiating the project (July 1972) we were able to precisely identify digital spectral signatures for various physical features including vegetation types.

The first signatures extracted via the ZTS included the total range of intensities found in each MSS band for selected training sets of vegetation types. Due to the heterogeneity among training sets many MSS signatures overlapped with each other and could not be used for computer classification. We refined signatures and separated vegetation types by arbitrarily deducting equal portions from each end of the intensity ranges within MSS bands. That procedure separated vegetation types but also left much of the area (about 50%) unclassified. Figure 3 shows results of such a classification for an area near Houston, Alaska in the Matanuska-Susitna Valley area. The black areas in the CDU display are unclassified picels.

Our next approach was to better define pure vegetation types to reduce heterogeneity. Training sets of 50 to 100 picels each were selected. Finding those sometimes proved difficult due to the irregular nature of natural vegetation boundaries.

Frequency distributions for training set spectral intensity levels were determined by totalling the number of picels for each level within each MSS band. That proved to be a most significant key to signature refinement because we often found that the frequency of intensities for certain signatures was not normally distributed about the median intensity. Thus, when we had been arbitrarily narrowing intensity ranges while refining signatures in the past, we were often unknowingly eliminating the most significant portions of certain signatures.

By determining frequency distributions we were able to determine modal intensities, at least some of the conflicts among types, and predict automated classification accuracy percentages. Also by calculating the variances within signatures we could estimate adequate sample sizes (picels needed per training set) for given levels of confidence in classification.

The technique provided very good automated classifications. And with the aspect ratio and skew correction programs developed for us by Tom Wetmore (ERTS-1 Project 110-1) we were able to produce classified printer plot maps at the 1:18,800 scale with classification accuracies ranging from 66% to 99+%.

We displayed our first classification results of digital data (September 1973) on the CDU-200 (color display unit) at Fairbanks. Maps (hard copies of useful products) were drawn from photographs of those displays. Problems in addition to signature refinement with that procedure were: (1) Not all of the 512 x 512 (picels) area could be displayed at once on the CDU 200; therefore, separate photographs were required for each variation of the display. Even with that approach the uppermost 32 scan lines could never be displayed due to the instrument's design. (2) There were two sources of geometric distortion in the displays. The first could have been partially corrected by programming procedures. The second was due to the curvature of the CDU's screen surface, and that could not be corrected.

Our refined signature classifications were then sent to the Dicomed Corporation of Minneapolis, Minnesota for color-coded digital printing. The resulting products were color transparencies which could be enlarged and printed as thematic maps. By comparing those classified transparencies with digital false-color transparencies of the same areas using bands 4, 5 and 7, obvious misclassifications could be readily recognized.

Thus, by using computer analysis to classify the mass of data and using human judgements only in areas where it was obviously needed, we developed a relatively efficient procedure for mapping Alaskan vegetation types. Once mapped this information can be combined with the general soil survey maps (available from the Soil Conservation Service) and topographic maps (available from the U.S. Geological Survey) to select sites possibly suited to various agricultural enterprises.

RESULTS OF DATA PROCESSING TECHNIQUES

Three steps were necessary in order to accomplish our primary objectives of utilizing ERTS data for vegetation mapping. First selecting the data format to use which would yield the most useful information. Second, correlating ground truth to the ERTS-1 data; and third, producing useful "hard copy" products.

Resolving those steps with respect to data format and equipment used was a most significant finding in this study. With that technology available, we were then capable of applying it in Alaska to provide crucially needed information. Thus, our methodology is detailed below.

Selecting Data Format

As previously mentioned, our choice of data format for mapping vegetation was the computer compatible tapes (CCT). Visual ERTS-1 products, 70 mm transparencies and 9.5 inch black and white prints and transparencies were used for quick look evaluations of scene usefulness for digital analysis. We designed a grid overlay for the 9.5 inch imagery so we could select CCT reel number, scan line and picels for given localities.

Relating ERTS Digital Data to Ground Truth

For signature extraction the Bausch and Lomb Zoom Transfer Scope proved to be a very valuable and critically needed tool because it permitted us to optically register the NASA-supplied aircraft data (ground truth) with digital MSS data and to define vegetation ecotone and training set boundaries in the digital data (Figure 4). For 512 x 512 (picel) areas the reflectance intensities in the digital data were listed separately as 10's and integers because only one numerical character could be printed per picel.

In our first attempts, boundaries between all integers were delineated with colored marking pens on the 10's listing for band 7. However, we discovered that it was more efficient to delineate just the zero's (reflectance intensities less than 10). This simple procedure was sufficient to identify bodies of water needed to geographically locate ground truth areas and accurately plot training sets.

Training sets of 50 to 100 picels each were selected within the boundaries of vegetation types that had been previously delineated on color infrared (1:40,000 scale) air photos. Training sets were marked on transparent plastic overlays that had been registered with the 10's and units listings of unclassified MSS data. Considerable care and judgement was used in locating blocks of vegetation of sufficient size and suitable uniformity for adequate and truly representative training sets.

Topographic variations, and even subtle intermixing of vegetation types introduced errors into the signatures. Experience indicated that the time for "lumping" signatures was in the signature refinement stage and not in the signature extraction step.

Once training sets were located, relatively uniform samples from six consecutive scan lines were drawn in order to balance the interscanner variations within signatures.. These sets were delineated on the transparent overlays so that those same picels could be identified when the overlay was registered on printer-plots from each of the four MSS bands.

Printer-plot listings of units data corresponding with the respective 10's listing were registered over a light table such that the intensity for each picel could be read. Then all picel intensities within training sets were counted for each MSS band.

From statistical analysis of intensity variations we calculated adequate sample sizes needed to include the mean intensity within a 2-level interval at 99% probability (Table 1). From these statistics, we found that: (1) In most instances, 50 picels was an adequate sample, and in the most variable types, 100 picels was a sufficient sample. (2) Band 6 was the most variable of the 4 ERTS-1 bands; and (3) modal rather than median intensities were good estimates of population parameters because frequencies were not always distributed normally about the median intensity.

From those and similar data, signatures were refined by evaluating frequency distributions of intensities. In instances where signatures were completely confused in all bands (Table 2) the types were pooled and combined-type signatures were calculated from the pooled data.

SIGNATURE REFINEMENT

Table 2 shows that by using frequency percentages in the digital signatures, we were able to estimate classification accuracies and refine signatures for the automated classification system. For instance, suppose intensity level 23 in band 4 was used to classify a "deciduous vegetation" type other than alder. From the training set data, we estimated that 14% of the alder is "Alder 3" (Table 2) reflected intensity level 23 in band 4. Thus, by using MSS band 4 level 23 for classifying a "deciduous vegetation" type we would have included about 14%.of the alder. However, suppose intensity level 27 of band 4 were used to classify a "deciduous vegetation" type. From the training set data we estimated that 2% of the alder in "Alder 3" reflected level 27 in band 4. Thus, by using MSS band 4 intensity level 27 to classify a "deciduous vegetation" type we would have included about 2% of the alder.

In the above example, the two intensity levels were the MSS band 4 extremes for the "Alder 3" training set. Without knowing the frequency distribution for intensity level, we might have supposed, during signature refinement, that the two levels (23 and 27) equally represented alder. But due to the skewed distribution of intensity levels, level 23 was 7 times more important to the alder MSS signature than level 27. Therefore, by using such frequency values while refining signatures, we were able to know not only where errors were being introduced, but also how great those errors were with respect to automated data processing.

From such data, classification accuracy tables were constructed for each area in the study (see Study Area Results). These tables were relatively reliable in evaluating signature validity before applying those signatures in the computer.

Producing Hard Copy

As mentioned earlier our approach to obtaining useable hard copy evolved through the photography of CDU-200 displays at Fairbanks to the Dicomed Corporation's color digital printer. The latter technique provided the superior products which are skew and aspect ratio corrected and can be either used directly as 1:532,200 scale products or enlarged to the 1:250,000 and 1:63,360 base map scales. Presumably the data could also be reduced to the 1:1,000,000 and 1:2,500,000 base maps, although we have not attempted that procedure. The important point being that such a product has great scale versatility and can be easily and quickly adapted to the needs of numerous users.

Some might argue that our digital processing is too slow compared to some systems wherein there is closer man-machine interaction for signature extraction. However, our needs for hard copy necessitates such a procedure and our experiences with such a system (CDU 200) have been unsatisfactory because: (1) the system has never operated properly since it was installed; (2) we were unable to superimpose small ground truth areas accurately on the display, thus, the reliability of displayed data remained unknown; (3) there was no means of estimating classification accuracies and (4) photos from the displays still had to be manually interpreted to produce hard copy. The latter step was unacceptable in our quest for reducing subjective judgement errors.

Suggested Improvements

Probably the greatest hindrance to our data processing procedure was in the areas of communication and data transferral (see Recommendations section). Since our laboratory was located about 315 miles (via highway) from the ERTS library and computer facility in Fairbanks, we were often inconvenienced by this arrangement.

The transferring of data and information during the processing of imagery and CCT data were shown in Figure 5. From actual experience, it took from 1.5 to 4.6 months for us to receive our completed hard copy. However, only a few days were actually spent processing and analyzing data. The rest of the time was spent "waiting for the mail."

Possible short cuts for the system would be in acquiring a color digital printer for producing hard copies locally. A second possibility would be to use local film processing facilities. A third possibility would be for our Palmer-based group to utilize University of Alaska, Anchorage, computer facilities.

The only deterrent to the first suggestion is in acquiring capital for the investment.

With respect to local film processors' work, either we have not been satisfied with their quality or we never knew how long it would take to complete an order or how much it would cost. Our only recourse has been to utilize the service of non-Alaskan commercial laboratories.

Upgrading present facilities and phasing toward establishment of a permanent remote sensing facility in the Palmer-Anchorage area would seem to be a reasonable improvement because approximately 56% of Alaska's potential ERTS users are located in the Anchorage-southcentral region (Table 3). Programs developed by Geophysical Institute (Project 110-1) could be used in other computer facilities, freeing their own operation for further research and development of new and better programs--a necessary shift if ERTS is to become operational in Alaska.

Now that we have some knowledge of how to work with ERTS-1 data, we need to develop a closer working association with potential user groups (Table 3) for bridging the gap between research and application.

For example, in a recent communication (Hutchison, 1974[1/]) from the U.S. Forest Service, they encouraged our continuing this work. They compared our results using ERTS-1 data with their conventional inventory method and found black spruce (a non-commercial tree) was sometimes classified as white spruce (a commercial tree); therefore, they suggested that we attempt to better refine that distinction.

1/ Personal letter to the Institute of Agricultural Sciences, University of Alaska.

RESULTS FOR TEST AREAS

Kenai Peninsula

There has been considerable interest in the vegetation and other natural resources on the Kenai Peninsula by various groups. Discoveries of natural gas deposits have prompted rather extensive seismic activity on the land, and off-shore drilling has been contemplated for Kachemak Bay. For years, fishing, wildlife, and recreational groups have expressed great interest in the Kenai resources. Members of the Joint Federal-State Land Use Planning Commission recently expressed a desire for more detailed vegetation maps showing vegetation distributions and extents on the Kenai National Moose Range. Lumber and forestry interests also need maps showing the extent of commercial forests. Sitka and white spruce as well as western and mountain hemlock all occur in that region.

Recently the state of Alaska through the University of Alaska's Institute of Agricultural Sciences established a branch research station on the Kenai Peninsula. The impetus for that development was to provide information that would assist red meat production on the Kenai. There are natural grasslands on the Kenai which have potential for beef production. Such resources have yet to be mapped, however.

Two 512 x 512 (picel) areas from CCT of scene 1390-20452 (17 August 1973) were converted to CDU-200 (Color Display Unit) compatible tapes. One area included the Homer Spit, portions of Kachemak Bay and northward toward the Caribou Hills. The other area included portions of Tustumena Lake and adjacent grasslands and forests.

Signatures were derived from both test areas and then during the refinement step, a combined-signature was derived for types common to both areas. Tables 4 and 5 contain the refined signatures for the "Homer" and "Tustumena" CDU areas, respectively.

Only three vegetation types could be distinguished in the CCT data near Homer, Alaska (Table 4). The grass type in that area included enough alder stands to prevent us from extracting separate signatures for alder and grass with confidence. It is important to note that separating the vegetation types only into those three classes yielded significant information. The wetlands are not suited to either farming or commercial forestry. Almost all coniferous forest stands in this area are of some commercial value. The alder-grass-deciduous forest type is believed to have domestic livestock grazing potential. Among the four vegetation types, in the Tustumena area the power to separate types was greater in the longer wavelengths (bands 6 and 7), except for distinguishing between grass and the alder-deciduous forest complex. Those two types were distinct only in band 5 (Table 5). The silty water of Tustumena Lake reflected much brighter (Table 5) than that in Kachemak Bay (Table 4). This difference in silty water signatures presented problems in other study areas. In band 6, the alder-deciduous type near Tustumena Lake reflected intensities from 34-49. For this type near Homer, the reflectance in band 6 was 40-60. Apparently, that discrepancy resulted from the complexing of that vegetation type with grass in the Homer area. Grass tended to reflect more energy in band 6 than did the deciduous trees and shrub.

As mentioned earlier it was possible to estimate errors that were introduced during signature refinement. These estimates were derived from percentages of intensities that were common to two or more features in training sets. These values were considered only as estimates since it was obvious that 100% classification accuracy was not possible considering resolution levels of the data and transition zones between features.

Therefore, a calculated accuracy of 100% would indicate a very high probability that that type was accurately classified, while a calculated accuracy of 79% would indicate a relatively lower probability for classification accuracy. We believed accuracies of 70% or better were acceptable and would result in products of value to Alaskan users. Also such accuracies were likely greater and contained more detail than most hand-drawn maps and certainly much better than any existing vegetation classifications.

Tables 6 and 7 contain the estimates of classification accuracies for the Homer and Tustumena areas. The lower accuracies were found in the more heterogeneous features, which was reasonable considering those features contained inclusions of other features which introduced variations into reflectance values. In contrast, relatively homogeneous areas such as bodies of water were probably classified more accurately.

The signatures that were used to produce the classified Dicomed print (Figure 6) and a printer plot map (Figure 7) for the Kenai Peninsula test area are given in Table 8. These were refined and combined from the Homer and Tustumena test areas. Judging from the increasing numbers of unclassified picels occurring in the upper one-fourth of the thematic map (Figure 6) the classification accuracy (Table 9) of the wetland and coniferous forest signatures was lower in that locality. Some of the unclassified areas on shore in the lower portion of the test area were agricultural fields and cultural developments (Figure 8). Unclassified areas just off shore in Kachemak Bay were either due to wave action or reflectances from the bottom features in shallow water. It was of particular interest that the boat harbor at the end of the Homer Spit was correctly classified as water. A low-angle oblique photo of that feature is shown in Figure 9.

Matanuska Valley

The Matanuska Valley is currently the agricultural center for Alaska. It is also rapidly becoming a haven for subdivisions spawned by the mounting demands for land from nearby Anchorage-ites who wish to escape the city life. Since those demands for land are great, there is understandably much interest in the land resources of this valley. The business center for the 23,000 square mile Matanuska-Susitna Borough is located in this valley which is surrounded by relatively rugged mountains.

There is also interest in supplying house logs and dimensional lumber for local and Oriental markets in the Matanuska Valley. Stands of cottonwood, aspen and birch offer a great potential for a pulp wood industry, too.

Certain lower slopes and high valleys of the surrounding mountains produce suitable range for domestic livestock. Numerous small brush fields on the valley floor, resulting from forest clearing activities, produce fine winter browse for moose. Lakes on the valley floor attract visitors and home builders to the area. Thus, considering the agricultural, forest, wildlife and recreational interests, the valley is quite valuable to Alaska.

There are no detailed large scale vegetation maps presently available for the Matanuska Valley. The 1:63,360 and 1:250,000 scale Spetzman map data currently available from the Joint Federal-State Land Use Planning Commission for Alaska are the best available information; but we have found those data to be relatively gross for management and resource inventory purposes having an estimated 60% accuracy in the Matanuska-Susitna Valley area.

Before the University of Alaska's CDU-200 became partially operational in the late autumn of 1973, we were confined to using visual interpretation techniques. By using the 9.5 inch transparencies of MSS bands 5 and 7 (scene 1390-20450) we constructed a 1:250,000 scale vegetation map via the Zoom Transfer Scope for the lower portion of the Matanuska Valley (Figure 10a). This map and a Spetzman's (Figure 10b) map from the Joint Federal-State Land Use Planning Commission for Alaska were compared to aircraft ground truth (Figure 10c). Classification accuracies were estimated by using a systematic sampling grid and registering the aircraft (ground truth) map with the ERTS-derived map and the Spetzman map independently. Classification accuracies were 81% and 62%, respectively, for the ERTS and Spetzman maps.

After the CDU-200 became available, 2 classified displays from MSS CCT data scene 1049-20505 were photographed with a 35 mm camera (Figure 3). Then 1:250,000 and 1:63,360 scale maps were prepared using the Zoom Transfer Scope (Figure 11 and 12). The average classification accuracy for that data was estimated at 92%, using a data sampling grid.

While examining these and other hand drawn maps it became apparent that there were two major errors inherent in this technique: (1) the subjectiveness on the part of the mappers in locating vegetation ecotones and (2) the difficulty of hand drawing fine details such as in areas where natural vegetation types intermingled. Both of those errors were diminished by using automated classification of CCT data.

Figure 13 is an uncorrected (geometrically) color-coded classification of MSS CCT data for a 512 x 512 picel area of the Matanuska Valley (scene 1390-20450). Signatures for the features recognized in the CCT data are given in Table 10.

The poorest classification accuracies were found in the rock, deciduous forest, mixed forest and the combined alder and grain-field signatures. (Table 11). Variabilities in type purity and topography are probably the major factors that weakened these signatures. For example, in a mixed forest south of Palmer the presence of a higher-than-usual number of spruce trees caused a few picels to be classed as scrubby spruce. This would be expected since the inclusion of small patches of spruce in the mixed forest stand would lower the intensity reflected in band 6 from the mixed forest signature to the scrubby spruce signature but not enough to match the commercial spruce signature.

In other instances alder on north and northwest facing slopes was shaded enough to change its signature to that of the deciduous forest type. Similarly shaded bare rock at times was misclassified as spruce.

From the practical viewpoint such errors were of lesser consequence to our project because most of the vegetation resources useful to agriculture and forestry occurred on the relatively level terrain of the valley floors. Also users having the corresponding false-color digital prints from unclassified (Figure 14) CCT data available could easily spot locations where topographic influences might have induced classification errors.

Comparing digital color printing (Figure 14) to photographically enlarging imagery for the same ERTS-1 scene (Figure 15) clearly demonstrated the superiority of the digital data with respect to resolution and content of useful resource information.

Shadows in mountainous regions such as the Matanuska Valley may be serious factors confronting users with particular interests in such localities. (It is apparent that in order to derive suitable signatures for programming, the area involved must be evenly illuminated.) Therefore, caution should be the rule in promoting ERTS-derived vegetation maps regardless whether manual or machine processing was used in producing such maps.

The 1973 CCT data from ERTS-1 were of better quality than the 1972 data according to the quality of false-color digital prints using bands 4, 5 and 7 (Figure 14 vs. Figure 17).

A false-color digital print of the Anchorage-Eagle River vicinity showed clearly the contrast between cultural developments and the natural vegetation (Figure 16). The urban as well as military installations appeared as light-blue areas in the reddish matrix on the Anchorage bench land between Cook Inlet and the Chugach Mountains.

Maps were also constructed at the 1:18,800 scales (Figure 18). Those maps were produced by the IBM 360/40 printer. In order for them to be useful to agency people, they must have: (1) township and range lines added and (2) type boundaries transferred to a better quality base, i.e. either a transparent or frosted plastic base material. Color-coded thematic maps are much easier to read than maps with symbols such as that in Figure 18.

Susitna Valley

The Susitna Valley lies between Cook Inlet and the Alaska Range. If all major tributaries are included, this is the largest valley in south-central Alaska. At least 8,800 square miles (Hegg, 1970) are included in this valley which includes the entire northern portion of the Cook Inlet Basin. The Susitna Valley is largely state owned and contains much area having potential for development of agriculture, forestry and other renewable resource uses. Due to its close proximity to nearly 1/3 of Alaska's human population (Anchorage), development is inevitable.

The Alaska Railroad and Anchorage-Fairbanks highway essentially parallel each other along the eastern side of this valley. There are a few settlements along these routes; however, most of the valley is accessible only by aircraft.

Coal and natural gas are fossil fuels known to be available in portions of the valley. Mineral resources are also present. Trappers and hunting guides have developed camps and homesites in many remote locations of the valley.

Since the area will surely be developed, resource data are needed if prudent planning is to be used prior to such developmental processes.

The first useable ERTS-1 imagery that we received (late October 1972) was acquired for the Susitna Valley 25 August 1972. A 512 x 512 (picel) area of that scene was analyzed from the CCT data. Signatures on this scene were used to compare signature validities for given vegetation types over distance (discussed in next section).

White spruce test areas large enough for signature extraction were not found in the ground truth data; therefore no spruce signatures were extracted (Table 12). In fact, finding test areas of scrubby spruce was somewhat difficult in the aircraft data transect, which extended west from near Talkeetna to the lower reaches of the mountains beyond Petersville.

Even with the aforementioned limitations in locating suitable training sets, the refined signatures we acquired were of significant value to mapping the vegetation of this region. The accuracy estimates for identifiable signatures were at least 70% or better (Table 13). Considering the present lack of vegetation maps for this area and the pending need for such, further application of ERTS data would appear beneficial.

Two color digital prints (Figure 19 and Figure 20) were made from CCT data. The false-color print (Figure 19) includes the western portion of the Peters Creek aircraft data transect in the Susitna Valley. The color-coded thematic map (Figure 20) includes the identical area of Figure 19 and was produced by using the signatures in Table 12.

Bonanza Creek Forest

On 25 August 1972, when the Susitna Valley data were collected, a partially clear scene was obtained for the Bonanza Creek vicinity near Fairbanks. Since another Alaskan ERTS-1 investigator (James H. Anderson, Project 110-3) visually interpreted and mapped vegetation from the Bonanza Creek imagery we were encouraged to compare our CCT results to his hand drawn maps. In addition, we were anxious to evaluate the extrapolation validity of digital signatures for vegetation types in that scene to signatures of like types in the Susitna Valley test area. The Susitna Valley test site was approximately 175 miles south and 75 miles west of the Bonanza Creek test area.

The Bonanza Creek area represents interior Alaska with the influence of a continental climate having greater temporate extremes than that of the Susitna Valley. The Susitna Valley lying between the Alaska Mountain Range and Cook Inlet is more strongly influenced by the mountains and the coastal climate. Areas of the interior are often underlain by permafrost while those of southcentral coastal regions are permafrost-free except at high elevations. Certain plant species are common to both locations, such as white spruce, paper birch, aspen, and cottonwood. However, the vegetation of all communities is not identical in both localities.

Six vegetation types were recognizable (Table 14) in the CCT data for the Bonanza Creek scene (1033-21011). We found that distinguishing between commercial spruce and scrubby spruce stands was easier than distinguishing between commercial spruce and clear water in the MSS digital data. Apparently, the relative openness of the scrub-type permitted deciduous vegetation to develop. Thus, the scrubby spruce vegetation had the same MSS signature as the mixed forest, which was distinct from that for pure stands of spruce. In the 1033-21011 scene, MSS signatures for cottonwood overlapped that for aspen and birch. Along the edges of birch and aspen stands, that type was misclassified as cottonwood (Figure 21).

Minimum classification accuracies of the MSS signatures in the CCT data ranged between 66% and 97% (Table 15). A color-coded thematic map produced by the D-47 printer (Figure 21) and a 1:18,800 scale printer plot map produced by the IBM 360/40 were examined; both compared quite well with aircraft ground truth (Figure 22). In an independent comparison of this classification with a timber-type map produced conventionally from 1962 aircraft data and ground observation, we discovered a rather remarkable similarity (Figure 23a and 23b) which was further emphasized when we compared the ERTS-1 data to aerial photography acquired in 1972 (Figure 23c).

In comparing the use of CCT data and imagery it was obvious that: (1) The visual interpreter subdivided the mixed forest types from wetlands (presumably scrub) and we were unable to clearly separate these CCT signatures. This was particularly noticeable in the Tanana River flats region. (2) The boundaries of both classifications did not coincide with each other. This was expected since delineating boundaries in natural vegetation types having broad ecotones is a subjective process. (3) The CCT data presented greater detail than could be drawn and labelled by hand. (4) The hand-drawn classification from visual products showed spruce types in areas that the computer classified as mixed forest. The computer classification signatures were quite strict in defining pure spruce because we had been careful to exclude scrubby spruce in order to locate commercial spruce stands with confidence.

The false-color digital print of bands 4, 5 and 7 (Figure 24) shows greater detail of cultural features than was apparent in the classified data (Figure 21). Such features as the Anchorage-Fairbanks highway, the Alaska Railroad, the Healy-Fairbanks power line right-of-way and farm roads (upper right corner of Figure 24) are quite obvious in the false color data and obscured in the 9.5 inch imagery and the color-coded vegetation map prepared from CCT data.

Considering the two data interpretation processes and the two digital data presentations, it was obvious that the false color and color-coded thematic maps were more easily interpreted and conveyed more detailed information than either the 9.5 inch color imagery or the visual interpretations of enlargements from that imagery.

Signatures between the Bonanza Creek scene and the Susitna Valley scene in the 1033 orbit were compared. Those signatures compared rather poorly (Table 16). If the Bonanza Creek signatures were applied to the Susitna Valley area, the best classification that could be expected was 67% in the scrubby spruce (a mixed forest type). None of the Tanana River (Bonanza Creek scene) silty water signature would have classified silty water in the stream flowing from the Tokositna Glacier in the Susitna Valley. On the average this signature extrapolation was calculated to have maximum and minimum accuracies of 29% and 13%, respectively.

Reversing the above extrapolation procedure and applying the Susitna Valley signatures to Bonanza Creek vicinity, would have produced a relatively better classification (Table 17). However, that result was still judged inadequate because the overall classification was only 40-43% accurate. Even though the Susitna Valley wetland signature would have included an estimated 100% of the Bonanza Creek wetlands, the Susitna Valley wetlands signature would probably error in the Bonanza Creek region by including non-wetland vegetation types with the wetlands at Bonanza Creek.

We do not know if atmospheric conditions and/or subtle phenological differences were responsible for the signature discrepancy between the two locations. However, we do know that silty water signatures varied greatly even within a 512 x 512 picel region in other test areas so that difference here was expected. This factor was apparently due to variations in silt source and stream loads, since sediment loads and chlorophyll contents (algal blooms) have been measured in ERTS-1 water signatures (Greenwood, 1974). We rather fortuitously photographed in color portions of the Susitna

Valley and interior Alaska from a commercial airliner on the day of the 1033 orbit. Judging from those photos, there was little if any visible difference in vegetation aspect between the two locations due to autumn color development in foliage (Figure 25 and 26).

From these experiences, we have concluded that caution should be exercised in extrapolating MSS signatures over great distances in Alaska even when the data were collected within a short time frame.

This limitation introduces an uncertainty that will have significant impact on: (1) the usefulness of ERTS data where ground truth is limited and (2) the cost of data analysis since more ground truth may be needed than previously estimated; ground truth acquisition can be a substantial cost item in data analysis expenditures (McKendrick, 1973).

NEW TECHNOLOGY

See results section.

CONCLUSIONS

We have found that ERTS-1 type data can be successfully used to produce vegetation maps for Alaskan locations. These maps are most accurate and highly detailed when prepared from the CCT data.

Also greater detail is present in "raw" CCT data when electronically enlarged than is present in the 9.5 inch imagery. These "raw" data when presented as false-color images using MSS bands 4, 5 and 7 can be interpreted by local users once those users are trained to recognize color-feature relationships. However, when such products are produced in combination with the color-coded thematic maps by computer analysis of digital signatures, even greater benefits result.

These presentations have significant value to local Alaskan users, since such a quality of data is non-existent for most of Alaska. We have learned from experience that some potential users were reluctant to use ERTS-derived products until they personally viewed our large scale maps (1:18,000 and 1:63,360).

We believe there were three reasons for that reluctance: (1) Most people are unsure of new technology and since the on-the-ground user in most agencies have limited funds with which to operate, they fear risking such funds or they have no funds allotted for supporting such work. (2) Some of the most publicized results from ERTS were based on rather tentative conclusions which later proved to be somewhat over optimistic. This introduced skepticisms that have been difficult to overcome. (3) Many potential users of vegetation maps have seen only the 1:1,000,000 scale imagery; and thus, they do not realize there is significantly more information available through properly using CCT data.

We calculated our current costs for producing camera-ready, full-color classified vegetation maps from NASA CCT (Table 18). These costs do not include: (1) ground truth, (2) NASA CCT ($160/ERTS-1 scene), and (3) printing costs (which should be recoverable in sales of the maps). Nevertheless, the current costs per square mile were estimated to be less than $\$2/mi^2$. In 1973 the cost estimate for a forest inventory of the Tanana River area in Alaska was $\$19.87/mi^2$. Air photos (1:15,840 scale) cost about $\$3.37/mi^2$ [2/]. The costs of aerial photography, plus ground control and uncontrolled mosaics in at least one instance exceeded $\$1,000/mi^2$ in the Prudhoe Bay area of the Arctic. Such aircraft data had substantially more

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[2/] Private communication from Keith Hutchison USFS, Juneau, in possession of the senior author.

resolution than ERTS-1 data and thus usefulness for other than vegetation inventories. However, for vegetative mapping the additional resolution and added information is probably unnecessary for usual management-scale maps (1:24,000 - 1:250,000).

We also calculated current costs for producing false-color digital prints from three of the four MSS bands (4, 5, and 7) (Table 19). Examples of these products appearing in this report show the apparent value of such data. For cultural, topographic and geological features these products are probably superior to the color-coded thematic maps. Total costs were estimated at \$0.58 - \$0.61/mi^2. These costs do not include: (1) price of the CCT data (\$160/ERTS-1 scene) and (2) printing costs for publication (which should be recoverable in sale of the imagery). Thus, if both classified and false-color products are produced for a given area, the cost would range between \$2.20 and \$2.60/mi^2. That estimate is higher than, but comparable with previous cost estimates by McKendrick (1973).

RECOMMENDATIONS

One of the greatest deficiencies we found with this project was in the data handling system. (See Suggested Improvements in the Signature Refinement section of this report.) The data for one ERTS-1 scene are collected during a 28-second period yet it may take nearly half a year for the processed data to reach the hands of users. Crea (1974) indicated ERTS-1 investigators reported waiting periods of 6 weeks to receive black and white imagery and then an additional 6-8 week wait for color composite and CCT data. Those estimates are accurate according to our experience. Combining the University of Alaska's data handling system, a well respected system according to Dragg (1972), and processing time requirement with the 12-14 week data delivery time adds up to at least 6 months from the time data are acquired before they become useable to the public.

We recommend that one significant improvement for the Alaskan system would be in acquiring equipment to produce full color hard copies of processed CCT data. Without such products the information derived on vegetation is useless to land managers.

For us, a data processing facility in southcentral Alaska would be a significant improvement. That may also benefit others in Alaska because the majority of users are based in that region. Furthermore, land-use and planning-curriculum students in the University of Alaska, Anchorage and Alaska Methodist University could become acquainted with this technology, an advantage they now do not have.

Apparently, investigators across the nation are going to have to take a more active part in promoting the use of ERTS by local users. We have found that some potential users in Alaska have been reluctant to apply ERTS-1 data to solving land use and vegetation resource inventory problems. This was most prevalent among local governments and was partially due to the lack of land management oriented personnel on those agencies' staffs. Persons having agricultural, forestry, range management and wildlife management training are usually more skilled at recognizing the value of land resource data than are persons with social and political science training.

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6. U.S. Department of Interior, Fish and Wildlife Service, Anchorage, Alaska.
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Union Oil Co.

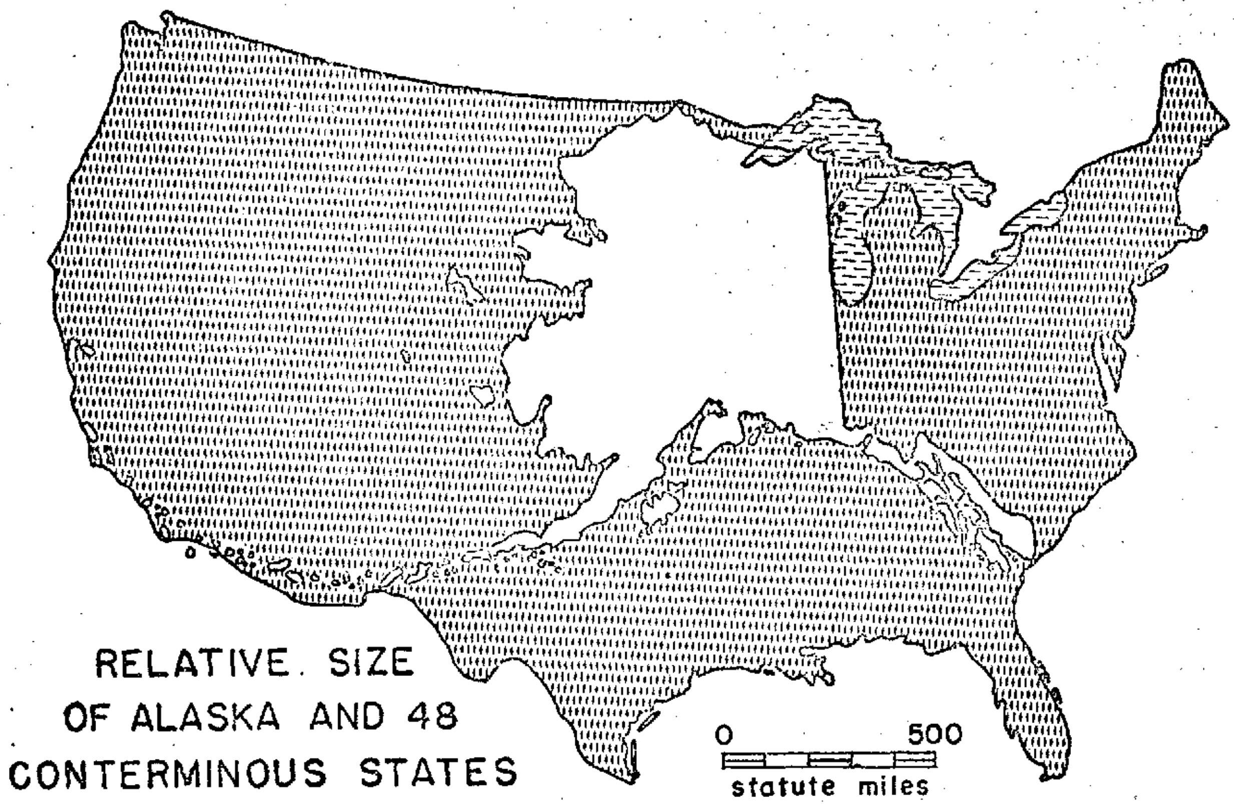
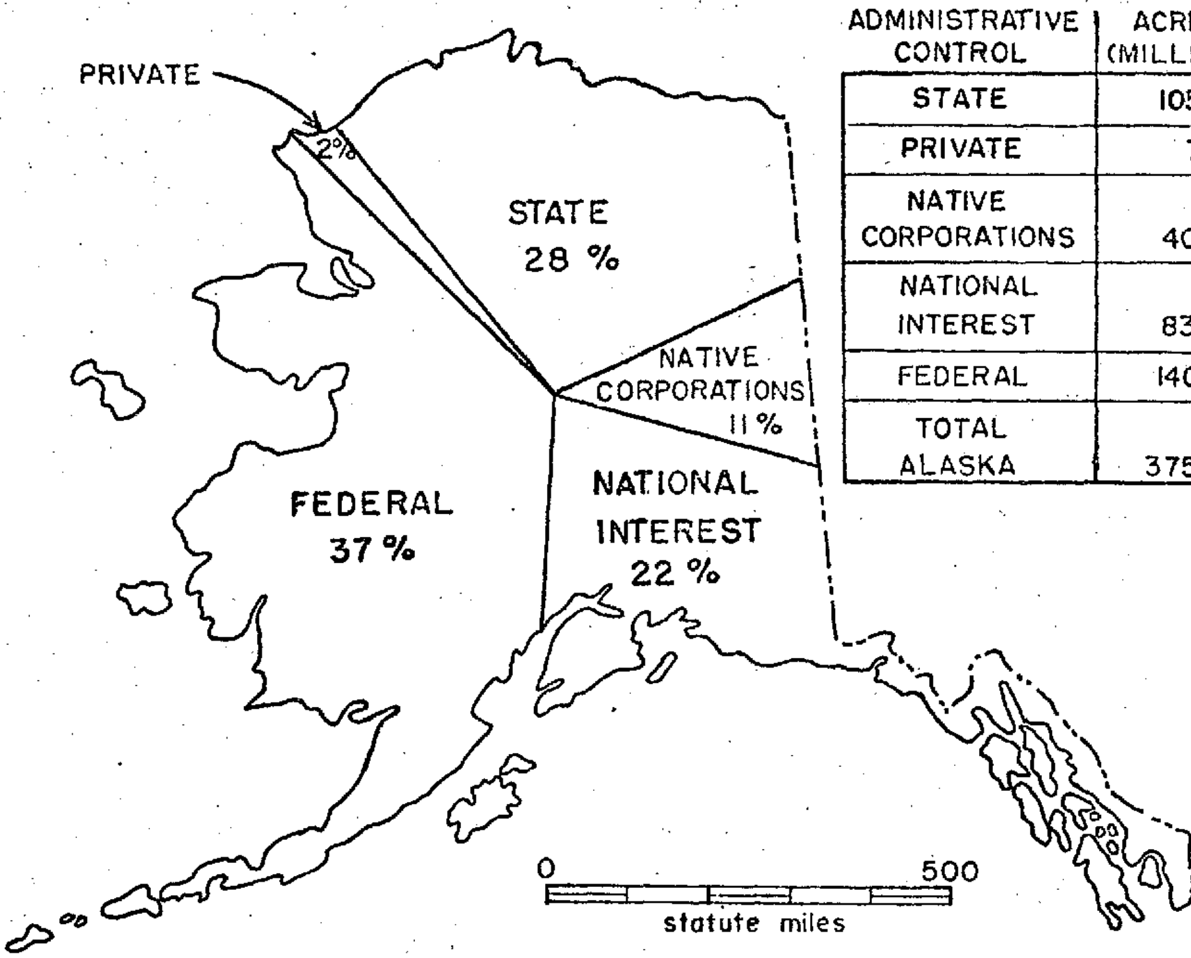


FIGURE 1. The outline of Alaska superimposed onto a map of the conterminous states. Alaska's land mass is approximately 1/5 that of the conterminous 48 states.



ADMINISTRATIVE CONTROL	ACRES (MILLION)
STATE	105
PRIVATE	7
NATIVE CORPORATIONS	40
NATIONAL INTEREST	83
FEDERAL	140
TOTAL ALASKA	375

ALASKA LAND STATUS

FIGURE 2. The relative land holdings by the major owners of Alaska's territory. Over 50% of Alaskan lands are in the process of being withdrawn by provisions set forth in the 1969 Statehood Act and the Alaska Native Land Claims Settlement Act of 1971.

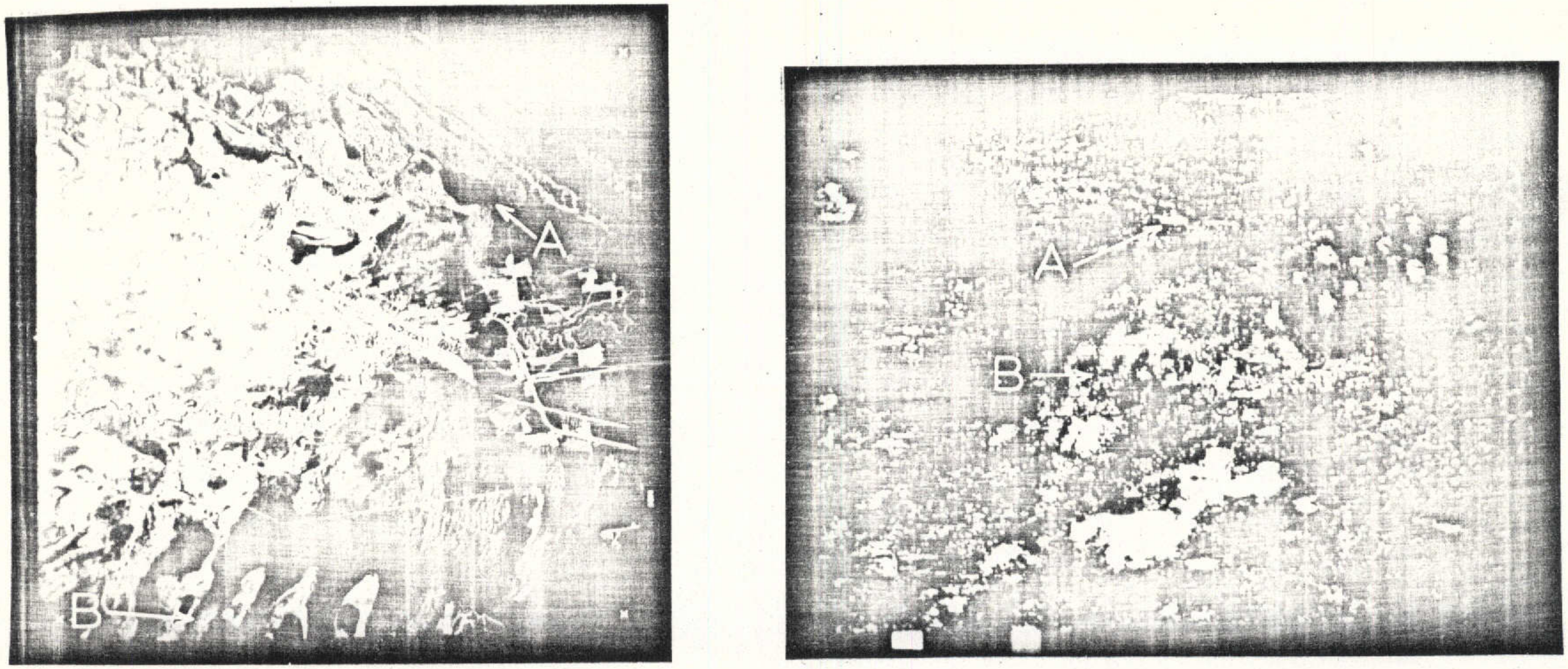
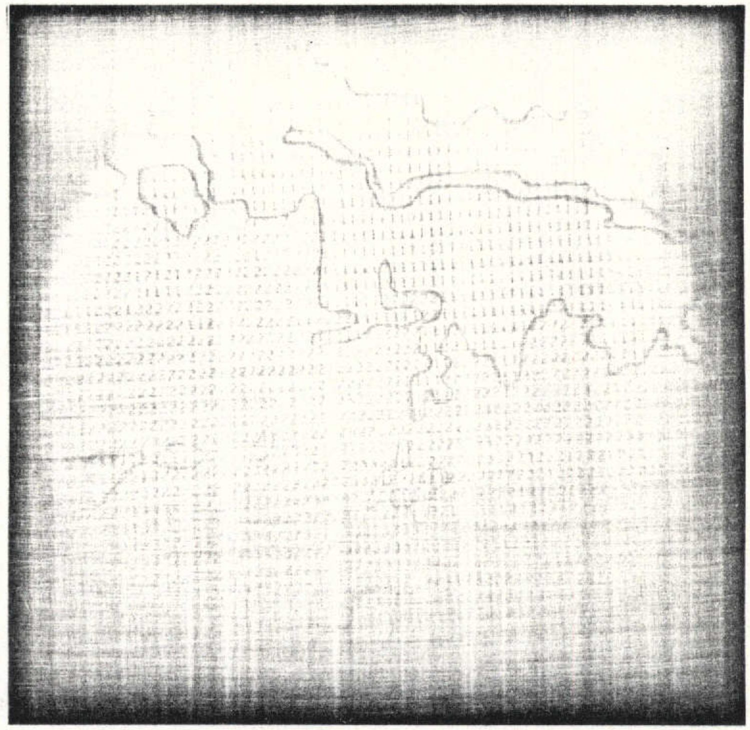


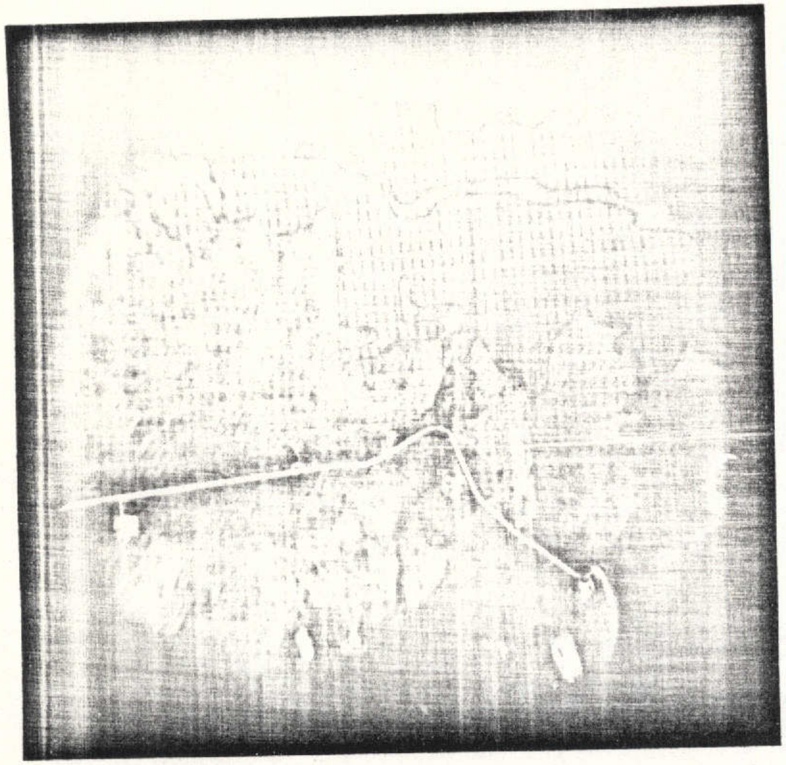
FIGURE 3. A reduction from 1:40,000 scale color infrared (CIR) ground truth (left) and a geometrically-uncorrected CDU display of classified MSS CCT data from the same locality (scene 1049-20505), Houston, Alaska. Red and blue-green in the CIR image correspond with deciduous and coniferous types respectively. Red, yellow-green, cyan and black in the CDU display correspond with deciduous, spruce, water and unclassified picels. In both Illustrations "A" points to an unnamed lake north of Houston; "B" points to a 16 acre stand of birch, correctly classified from ERTS-1 digital data.

(4a)

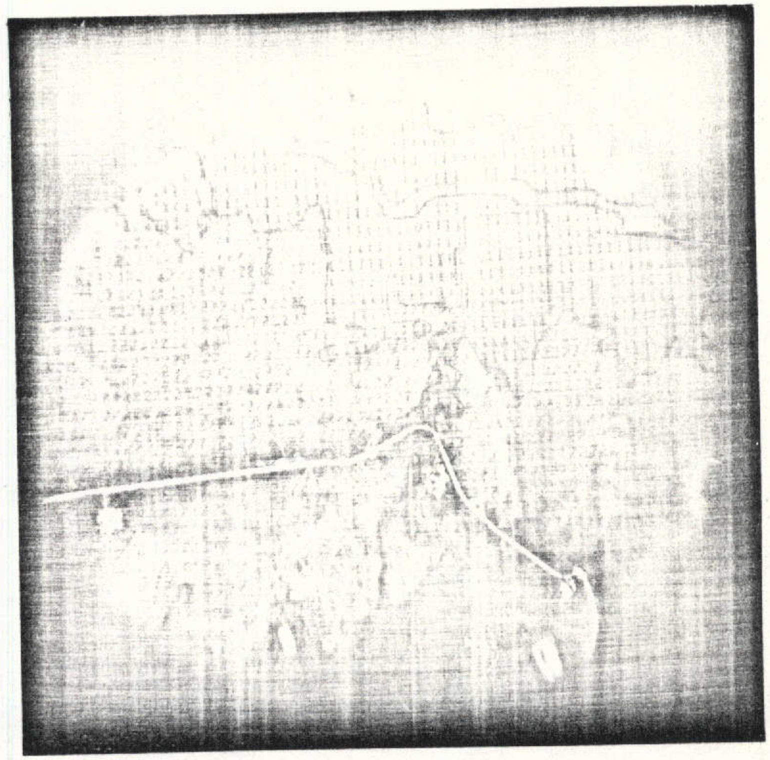


(4b)

FIGURE 4. Four views of about 5 square miles through the Zoom Transfer Scope (ZTS). Figure 4a is CIR ground truth aircraft data near Homer, Alaska. The red and pink colors correspond with the alder-grass type; the black corresponds with coniferous forest. 4b is a computer listing of reflectance intensities grouped by 10's for picels in MSS band 7 for the same area as the ground truth.



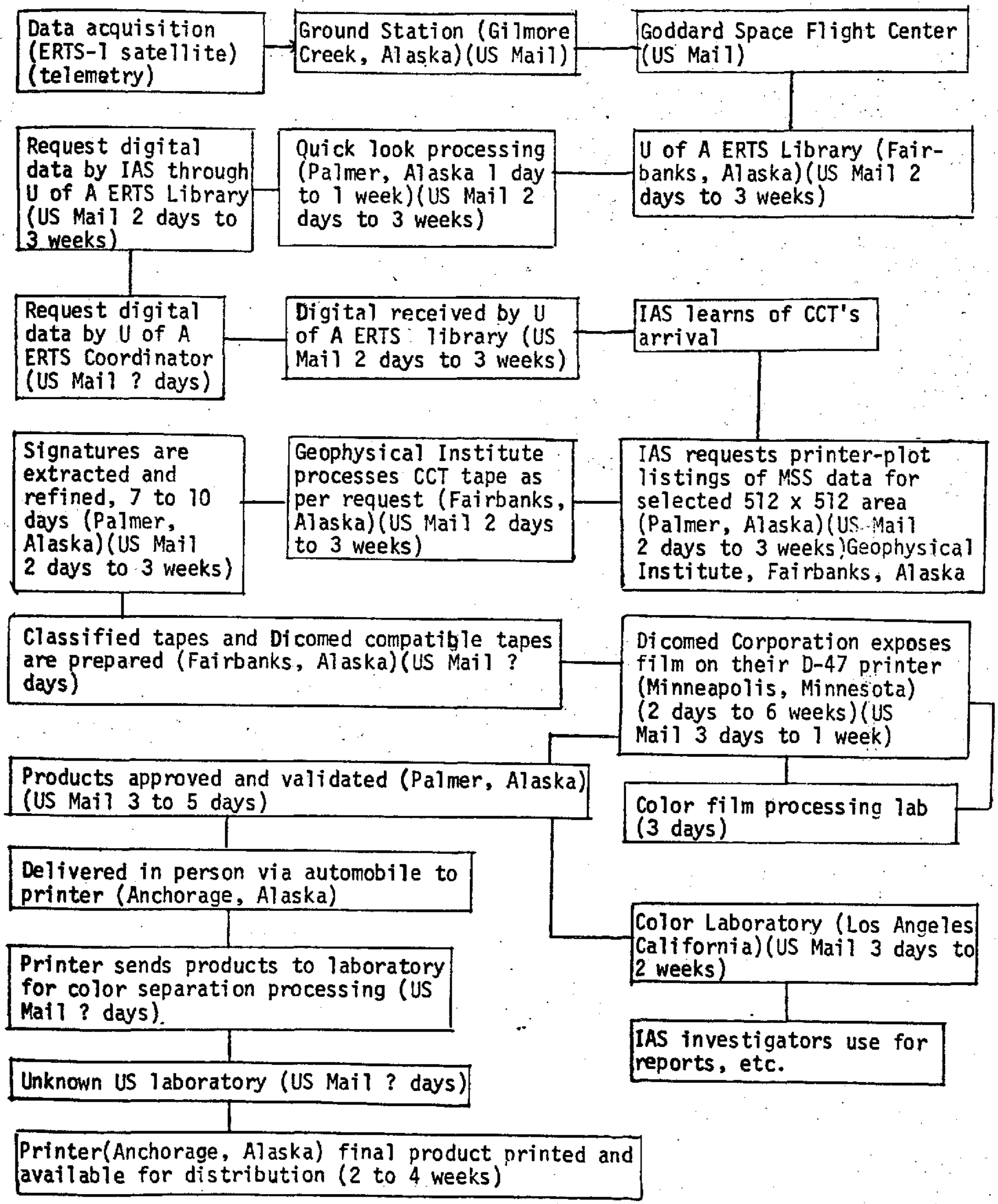
(4c)



(4d)

FIGURE 4 (Cont.) 4c is the 10's listing superimposed on ground truth, and in 4d two 50-picel training sets are delineated on the intensity listing. (ERTS-1 scene 1390-20452).

FIGURE 5 DATA FLOW CHART FOR INSTITUTE OF AGRICULTURAL SCIENCES ERTS-1 PROJECT



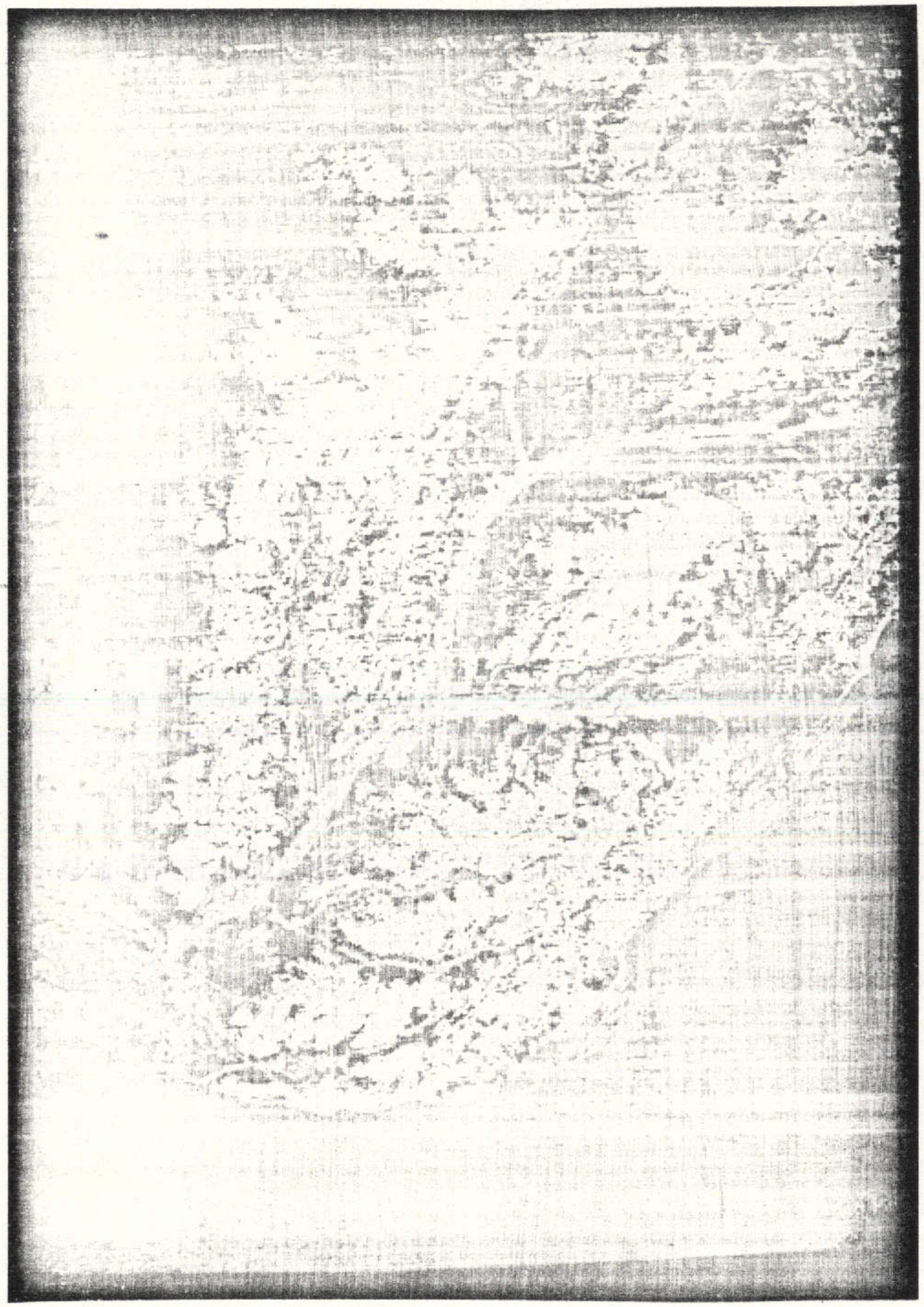
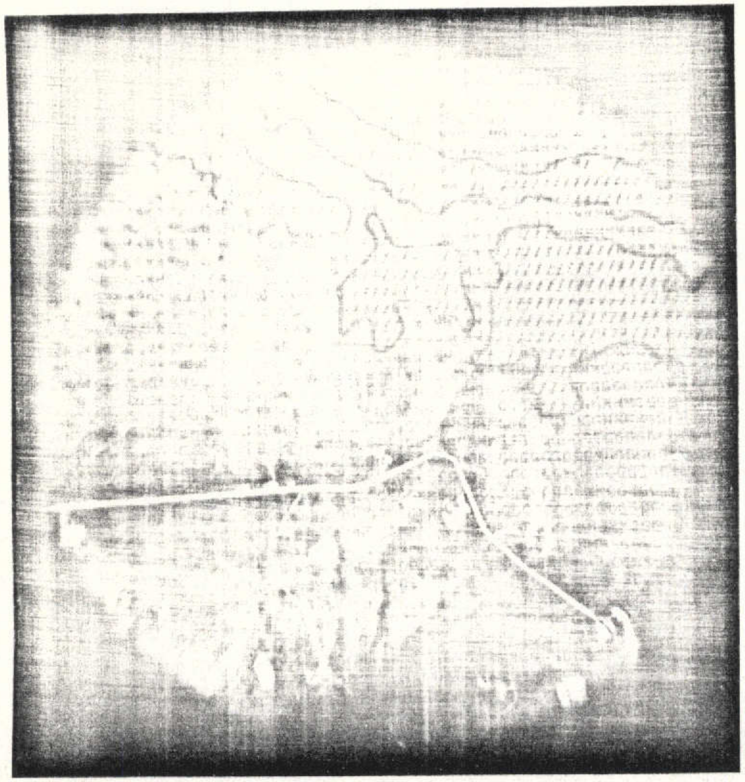
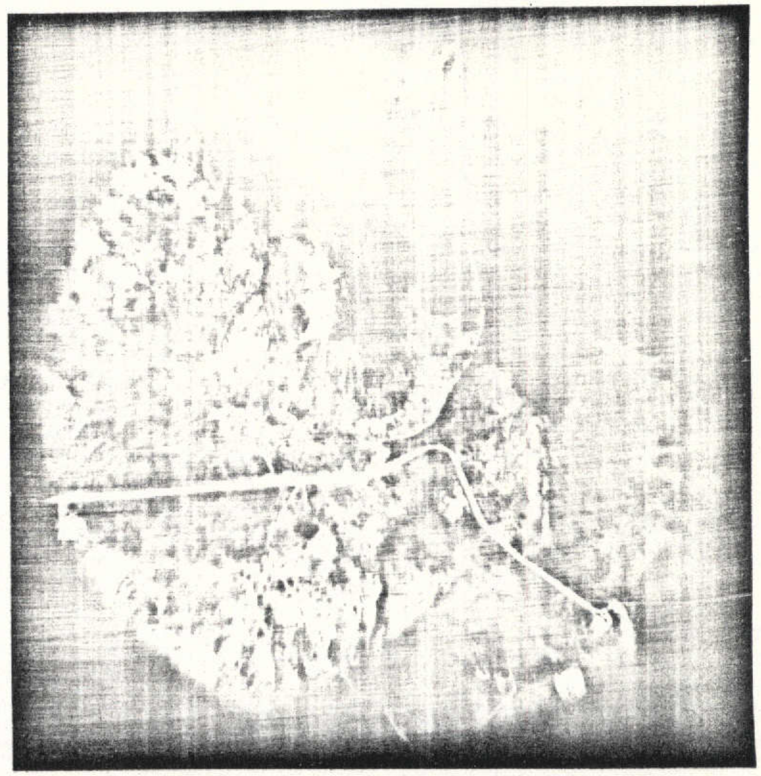


FIGURE 6. A color-coded geometrically corrected vegetation map (for about 500 square miles) produced from computer classified MSS CCT data (ERTS-1 scene 1390-20452) for the Homer, Alaska area. Yellow = alder/grass; green (confused with black in reproduction) = coniferous forest; purple = wetlands; blue = water; brown = rock and bare ground; black = unclassified picels. (Note the boat harbor at the tip of the Homer Spit--compare with Figure 9.) (Image produced via the Dicomed D-47 digital printer.)

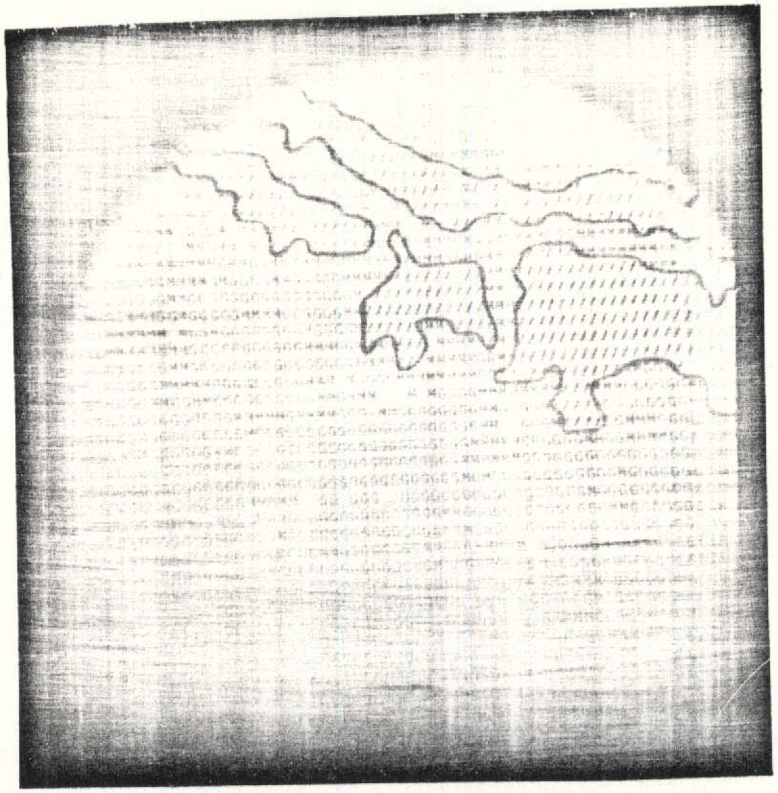


(7a)



(7b)

FIGURE 7. Three (5 square miles) views through the ZTS. Computer classified MSS data from CCT for scene 1390-20452 superimposed onto CIR ground truth (7a). CIR ground truth (aircraft data) alone (7b).



(7c)

FIGURE 7 (Cont.) Classified computer print-out of data (7c). Compare with Figure 4.

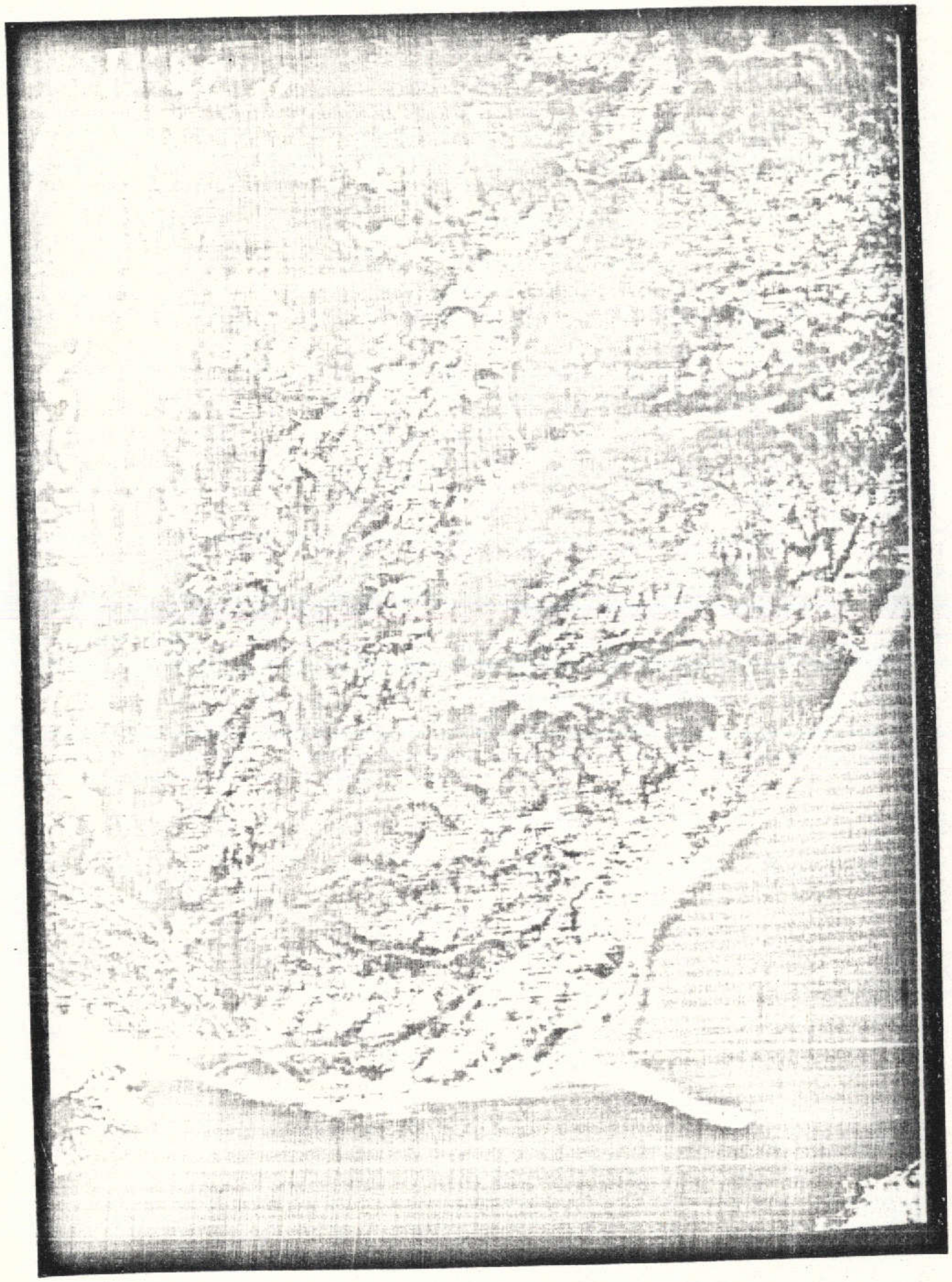


FIGURE 8. A geometrically-corrected false-color display of ERTS-1 digital data, MSS bands 4, 5 and 7, for the Homer, Alaska area. This is approximately a 500 square mile area and is comparable with that shown in Figure 6. (Image produced via the Dicomed D-47 digital printer.)

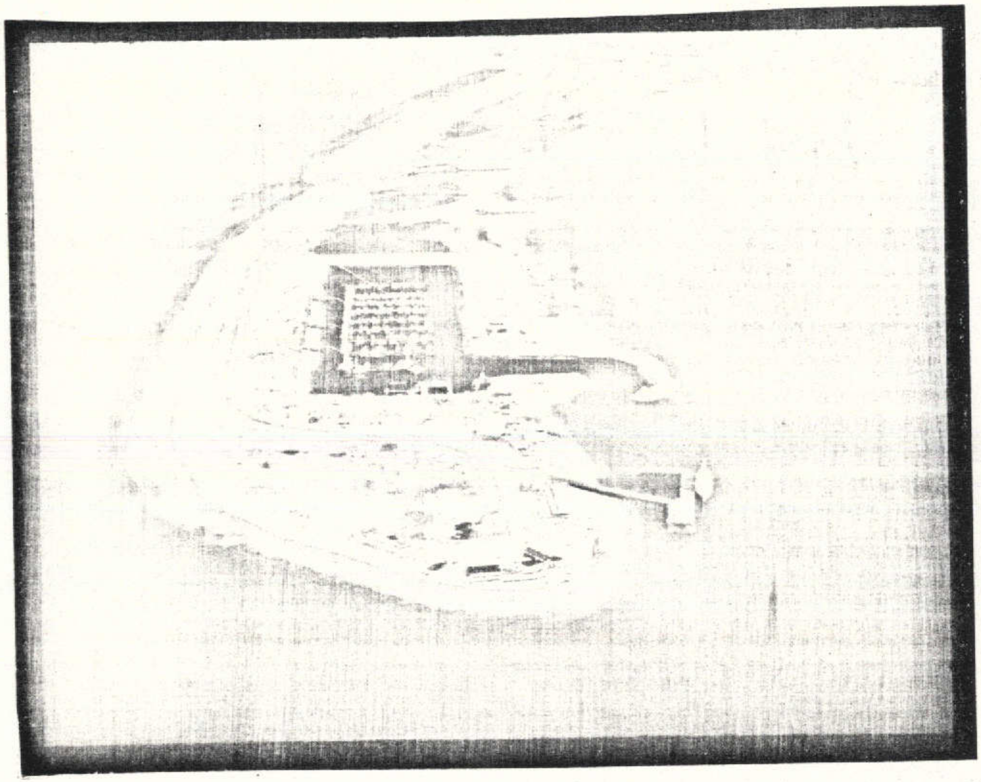


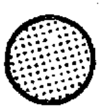
FIGURE 9. An oblique aerial view of the tip of the Homer Spit. See also the ERTS-1 imagery Figure 6 and Figure 8.

FIGURE 10. Photo reductions of 1:250K scale maps of the Matanuska Valley.

KEY TO VEGETATION TYPES

1. Barren
   (a) Gravel Bars
   (b) Burns
   (c) Rock

2. Deciduous Forest
   (a) Birch
   (b) Aspen
   (c) Cottonwood



3. Coniferous Forest
   (a) Black Spruce
   (b) White Spruce
   (c) Sitka Spruce
   (d) Western Hemlock

4. Grass

5. Shrubs
   (a) Tall Willow
   (b) Tall Alder
   (c) Low Willow
   (d) Low Alder

6. Tundra
   (a) Wet Tundra
   (b) Dry Tundra

7. Wetlands
   (Muskeg & Bog)

FIGURE 10a. A visual interpretation of vegetation types from ERTS-1 MSS bands 5 & 7, scene 1390-20450.

FIGURE 10b. Spetzman's vegetation map as interpreted by the Land Use Planning Commission.

FIGURE 10c. Aircraft ground truth manually interpreted.

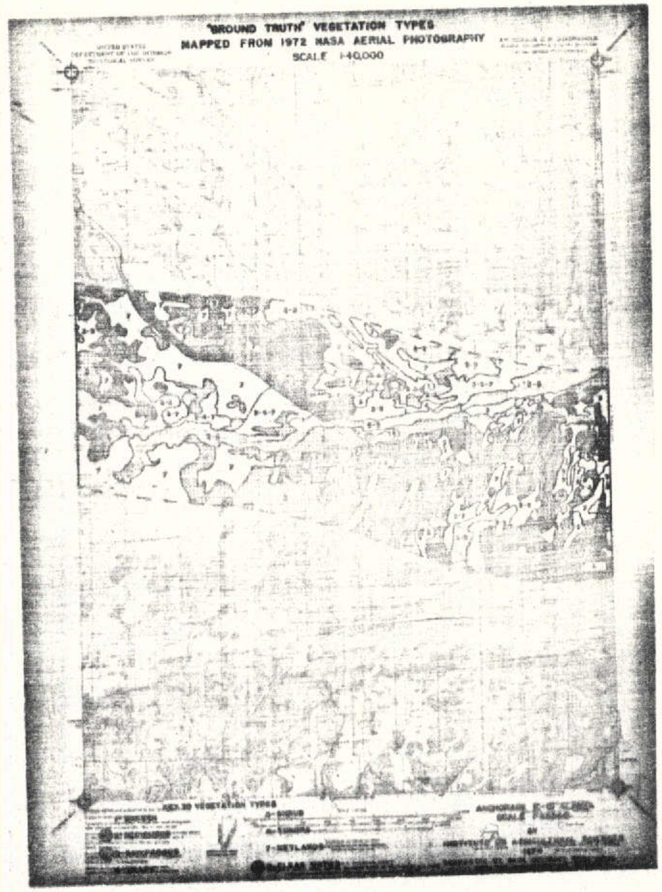
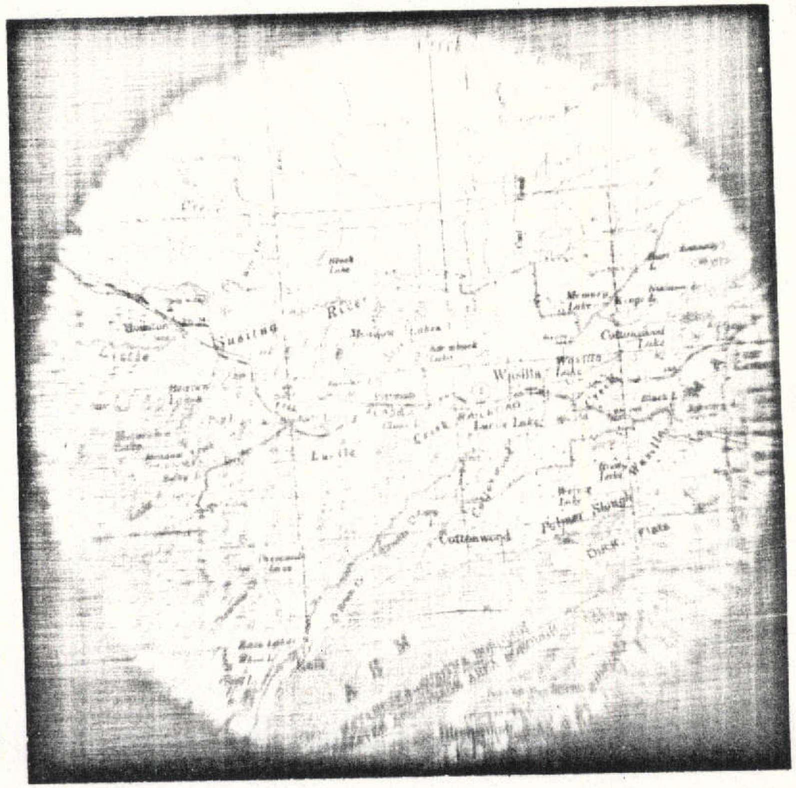


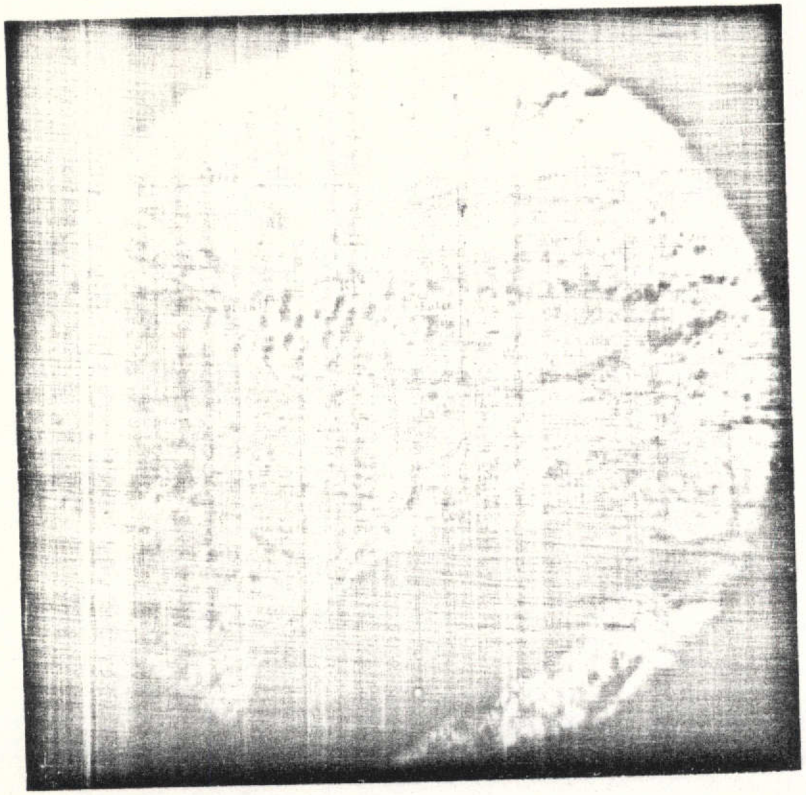
FIGURE 11. Photo reductions of vegetation maps (1:63,360 scale) prepared by manually transferring computer-classified CCT data, ERTS scene 1049-20505, from a 35 mm photograph of a CDU display onto a base map via the ZTS (left). Visually interpreted ground truth from CIR aircraft imagery also manually transferred to the same 1:63,360 scale base map via the ZTS (right).

(12a)

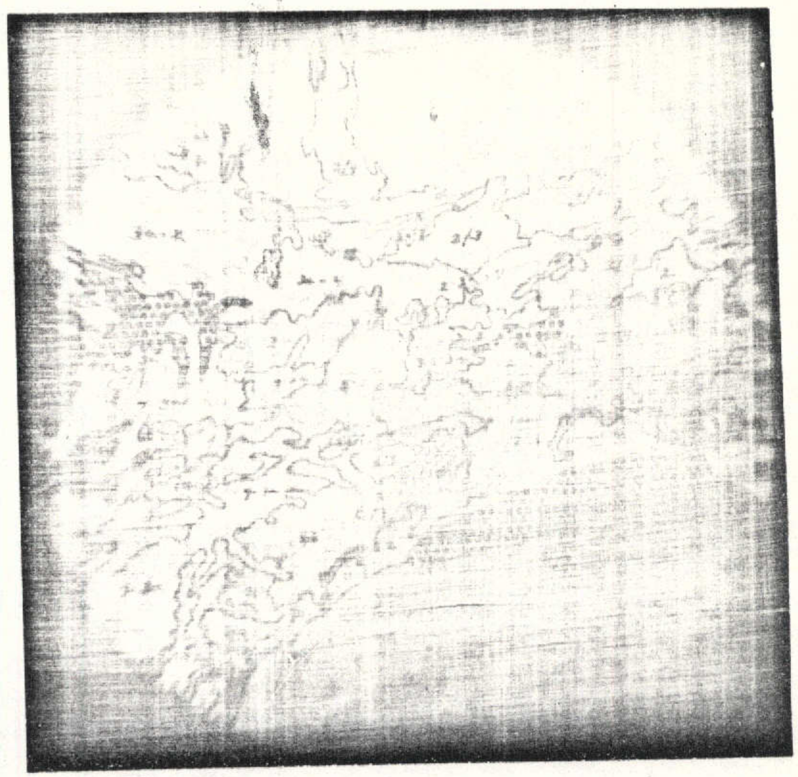


(12b)

FIGURE 12. Four views of a 530 square mile portion of the Matanuska Valley through the ZTS. Black and white ERTS-1 9.5 inch transparency band 7 (1390-20450) (12a). Same area on USGS 1:250,000 base map (12b).



(12c)



(12d)

FIGURE 12 (Cont.) USGS base map and ERTS imagery superimposed (12c). Visual interpretation of vegetation types from ERTS-1 imagery superimposed onto USGS base map (12d). See Figure 10 for vegetative legend.

FIGURE 13. A geometrically-uncorrected computer classified vegetation map from ERTS-1 MSS CCT data. This 500 square mile area is in the Matanuska Valley and is identical to that shown in Figure 14. (ERTS-1 scene 1390-20450.) Colors and their corresponding vegetation types are: black = unclassified; blue = water, yellow = tundra and grass; pink = alder (and sometimes grain fields); dull red = scrubby spruce; green (confused with black in reproduction) = commercial spruce; cyan = mixed forest; bright red - deciduous forest; brown = bare ground and rock; purple = wetlands. (Image produced via the Dicomed D-47 digital printer.)

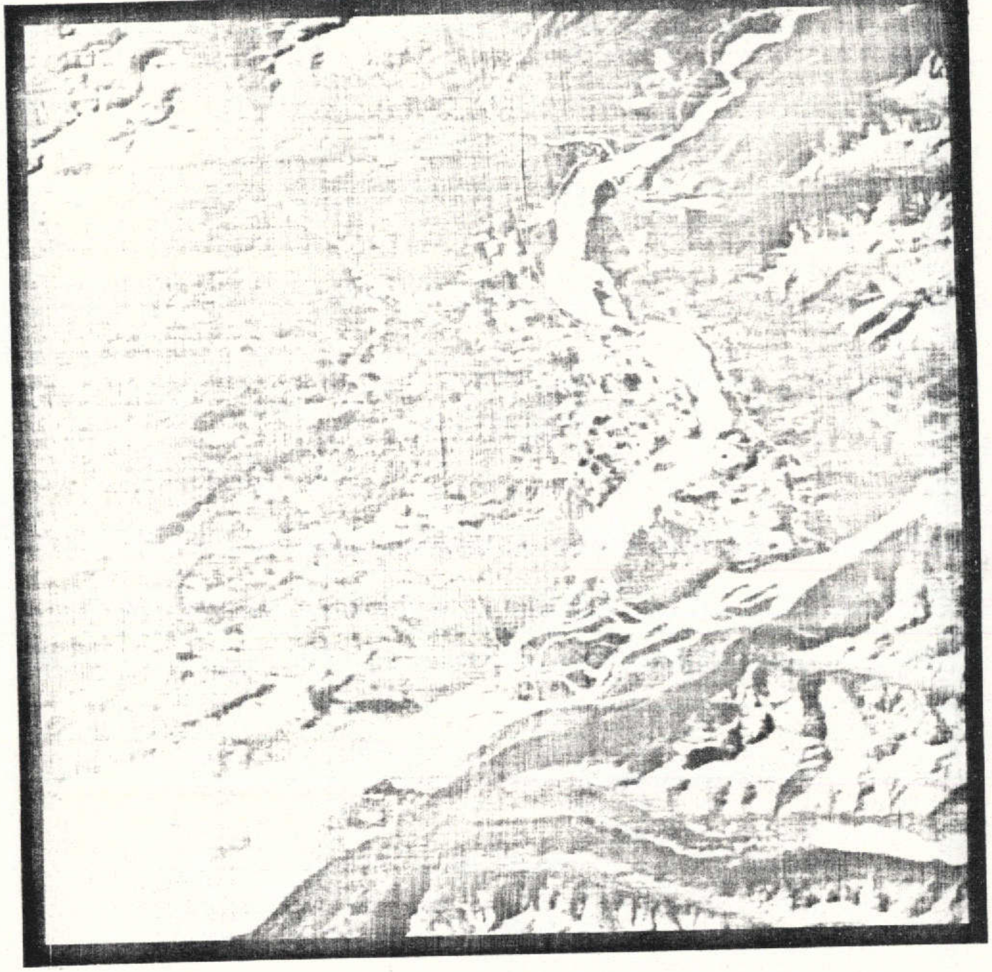


FIGURE 14. A geometrically uncorrected false-color image of ERTS-1 digital data, MSS bands 4, 5 and 7 for about a 500 square mile area of the Matanuska Valley, Alaska (ERTS-1 scene 1390-20450). Colors correspond closely to those of color infrared aerial photographs. Cyan = silty water or bare ground; black = clear water or shadows; light yellow = sparse vegetation, fields or tundra; pink = grasslands; dark blue = spruce; dark red = deciduous forest. (Image produced via the Dicomed D-47 digital printer.)

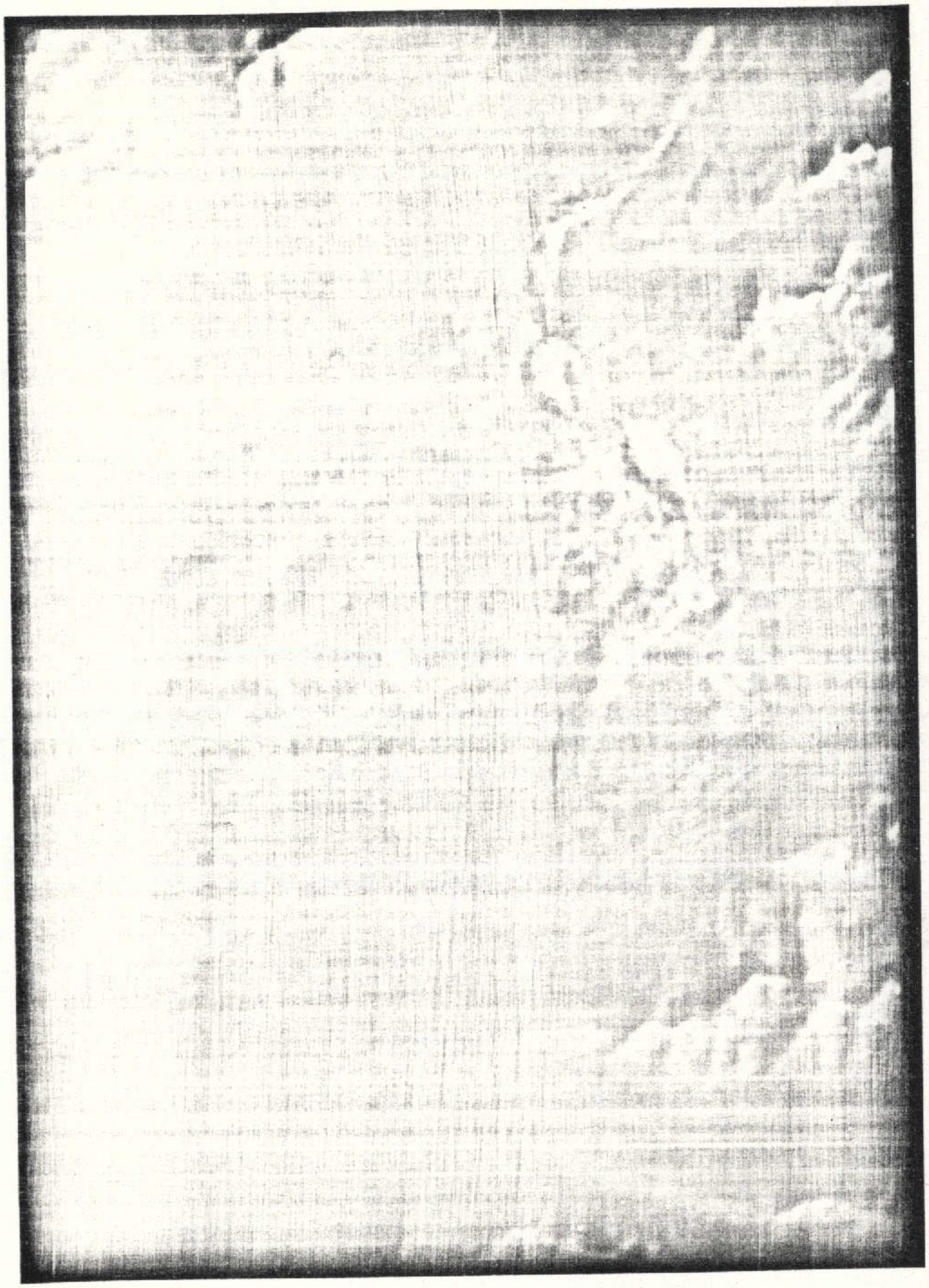


FIGURE 15. A part of an ERTS-1 scene presented in false color. This product was produced photographically by the Geophysical Institute, University of Alaska. It was enlarged from imagery of scene 1390-20450 and is of the same area shown in Figure 14.

FIGURE 16. A geometrically-corrected false-color print from ERTS-1 digital data of the Eagle River-Anchorage, Alaska vicinity from MSS bands 4, 5 and 7 (ERTS-1 scene 1390-20450) 17 August 1973. (Image produced via the Dicomed D-47 digital printer.)

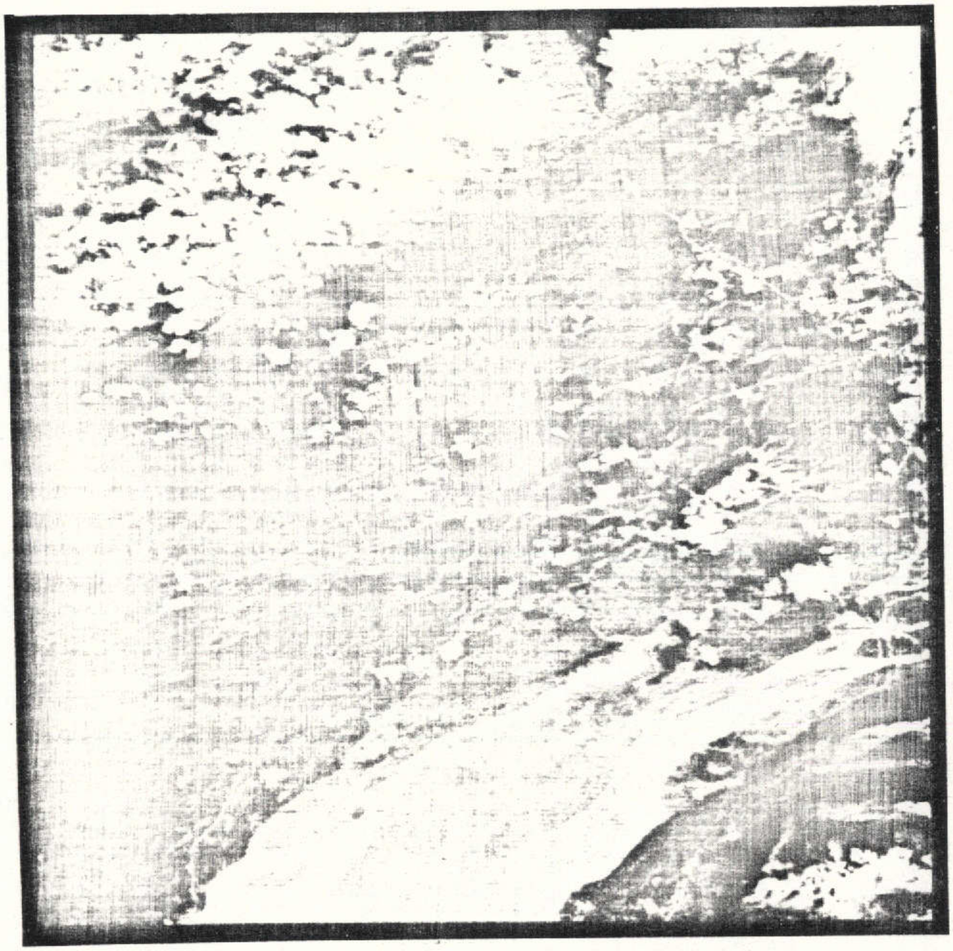


FIGURE 17. An uncorrected false-color image of ERTS-1 digital data from MSS bands 4, 5 and 7. It shows a portion of the Matanuska Valley, Alaska. Note this is 1972 CCT data (ERTS-1 scene 1049-20505). Compare it to that shown in Figure 14. (Image produced via the Dicomed D-47 digital printer.)

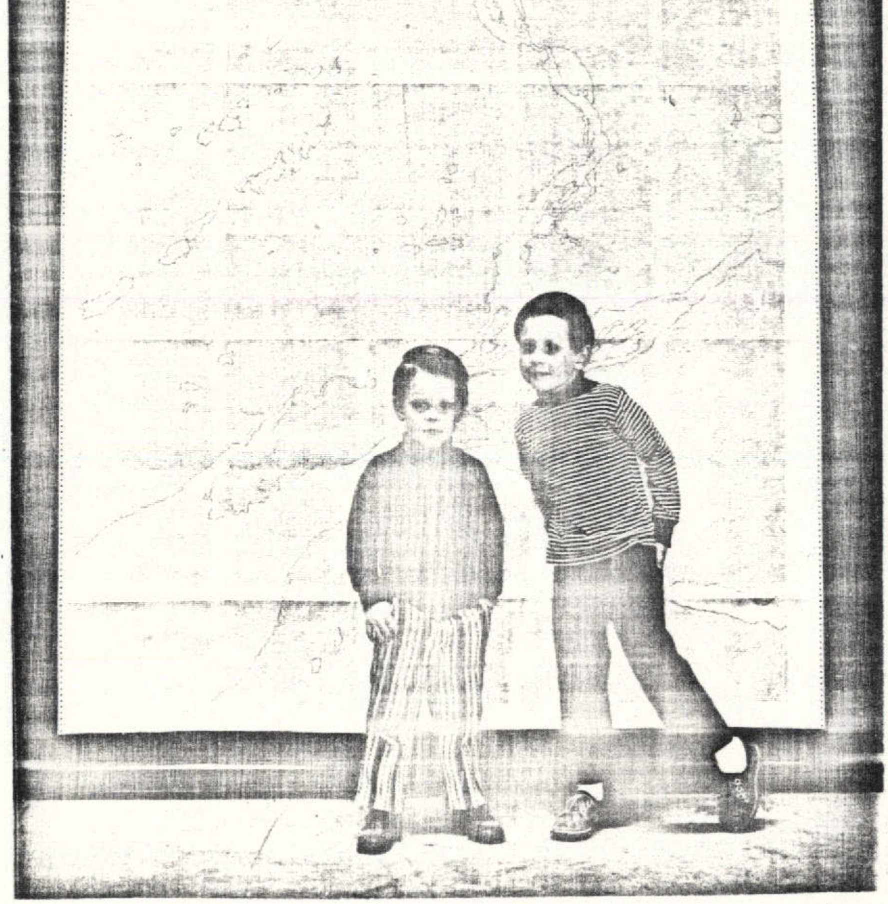


FIGURE 18. 1:18,800 scale computer printer-plot map (ERTS-1 scene 1390-20450) of the Matanuska Valley, Alaska with vertical and horizontal scales corrected. This symbol-coded vegetation map is the same classification as shown in Figure 13. Vertical and horizontal distances across this map are 85 and 61 inches, respectively. Water boundaries have been manually delineated on this display to orient the reader's attention to those features.

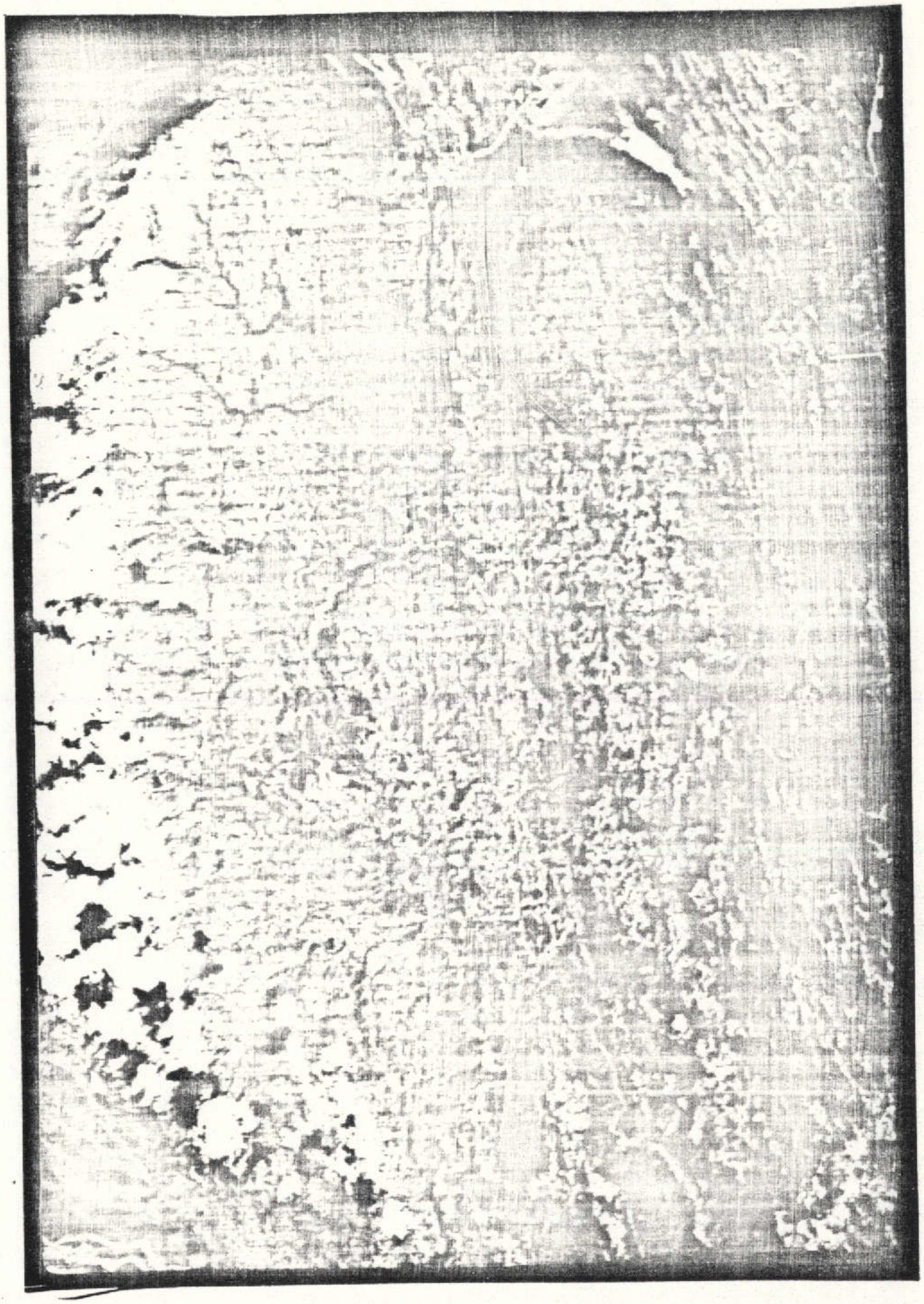


FIGURE 19. A geometrically-corrected false-color image for about a 500 square mile area in the Susitna Valley, Alaska produced from MSS CCT data bands 4, 5 and 7 (ERTS-1 scene 1033-21020.) A portion of the Anchorage-Fairbanks highway shows as a cyan-colored line in the extreme upper right corner. (Image produced via the Dicomed D-47 digital printer.)

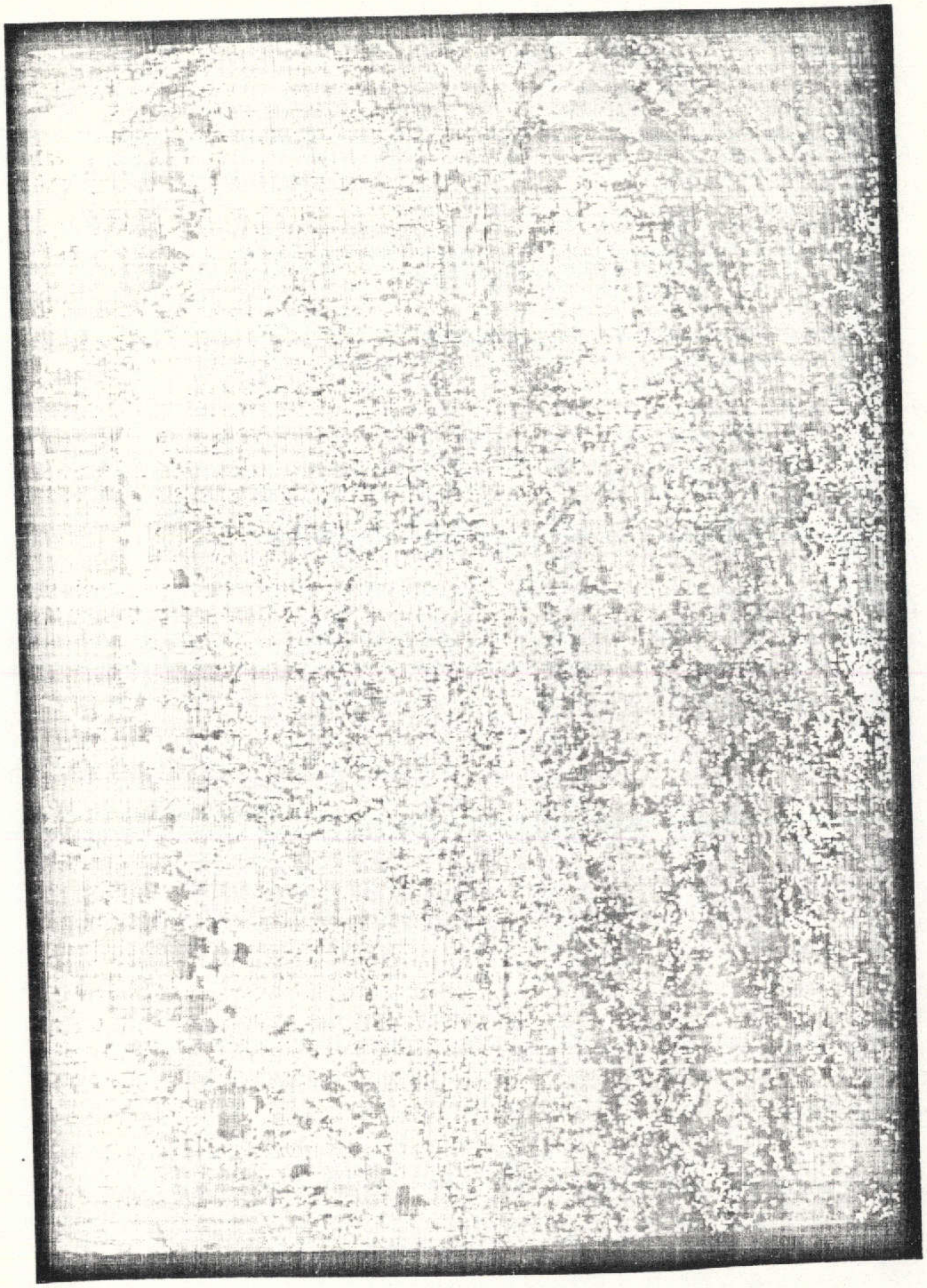


FIGURE 20. A geometrically-corrected color-coded vegetation map from MSS CCT data of the identical area shown in Figure 19 for the Susitna Valley, Alaska (ERTS-1 scene 1033-21020). Color codes are: black = unclassified; blue = water; red = birch; cyan = mixed forest; yellow = grass and/or alder; violet = scrubby spruce; purple = wetlands. (Image produced via the Dicomed D-47 digital printer.)

FIGURE 21. A color-coded, geometrically-uncorrected vegetation map of the Bonanza Creek area near Fairbanks, Alaska. This 500 square mile area was mapped from MSS CCT data ERTS-1 scene 1033-21011 (25 August 1972). Black = unclassified; yellow = cottonwood and/or deciduous; red = birch and/or aspen; cyan = mixed forest including scrub; violet = wetlands; pink = tall shrub; blue = water which was sometimes confused with spruce; green = commercial spruce. ("Box" includes area shown in Figure 23.) (Image produced via the Dicomed D-47 digital printer.)

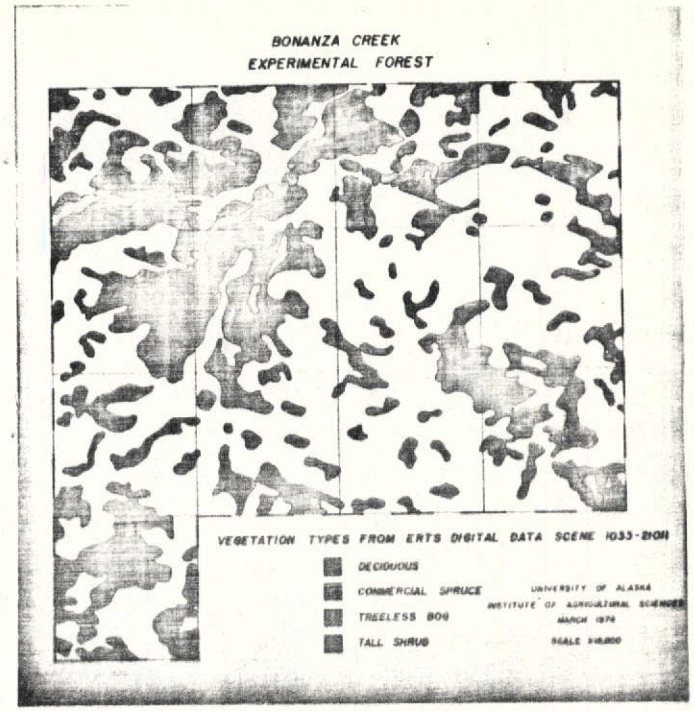
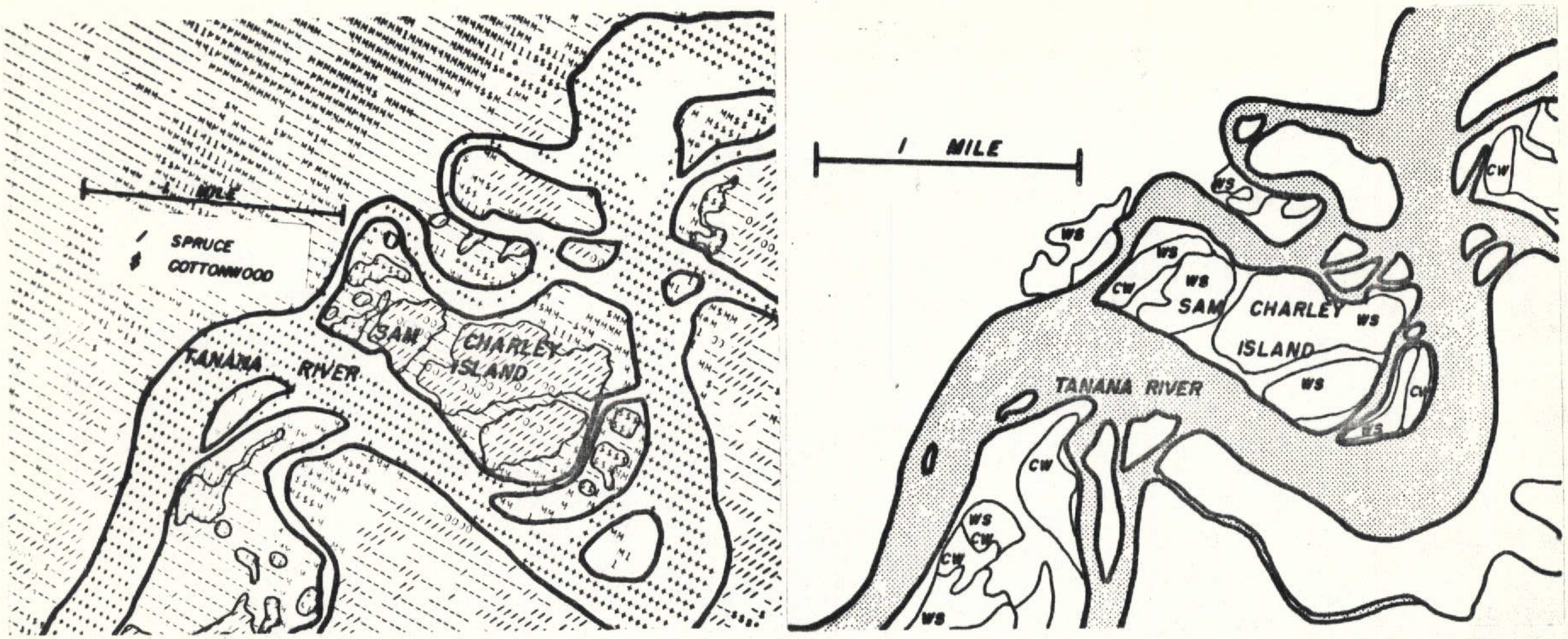


FIGURE 22. 1:40,000 CIR aircraft data "ground truth" of the Bonanza Creek Experimental Forest area (left) compared with ERTS classified digital data (scene 1033-21011) printed for the same area on the IBM-360/40 computer (right). Included with these photo reductions is a sectional grid with each block representing 1 square mile. The ERTS data was printed originally at a scale of 1:18,800.



(23a) (23b)

FIGURE 23. A portion (same area as "box", Figure 21) of an aspect-ratio corrected classified computer printer-plot map (MSS CCT data, scene 1033-21011, 25 August 1972) (23a) and the same area mapped manually by the Alaska Division of Lands (23b) from 1:15,840 scale air photos (obtained in 1962) for the Sam Charley Island region of the Tanana River, southwest of Fairbanks, Alaska. Notice that the / and $ in the ERTS-1 data correspond respectively to WS (white spruce) and CW (cottonwood) in the conventional timber inventory map. + = silty water; -- = mixed forest; 1 = tall shrub; M = wetland; 0 = clear water and sometimes spruce.

(23c)

FIGURE 23 (Cont.). Ground truth (23c) for Sam Charley Island taken from 1:40,000 color photography acquired during the summer of 1972. Notice the shape of the islands and river in the ERTS digital data more closely resembles that of the recent aerial ground truth data than it does the vegetation map drawn from 1962 aerial photography.

FIGURE 24. A geometrically-corrected false-color image for a 500 square mile area in the Bonanza Creek area southwest of Fairbanks, Alaska produced from MSS CCT data bands 4, 5 and 7 (ERTS-1 scene 1033-21011, 25 August 1972.) This area is identical to that shown in Figure 21. (Image produced via the Dicomed D-47 digital printer.)

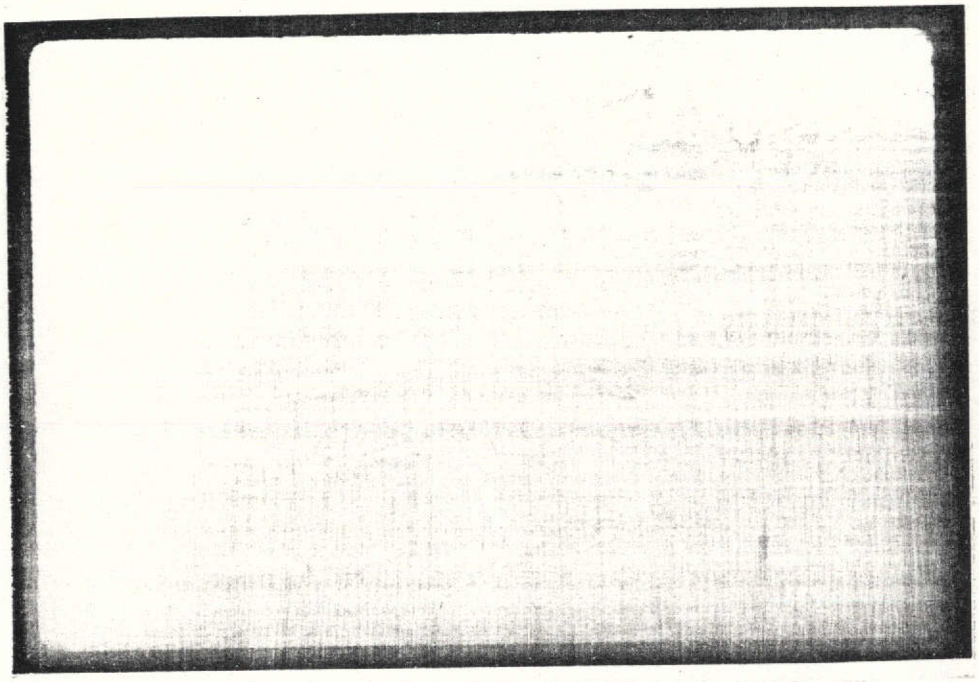


FIGURE 25. An oblique aerial view of the upper Susitna Valley, Alaska looking toward Mt. McKinley and the Alaska Range (25 August 1972).

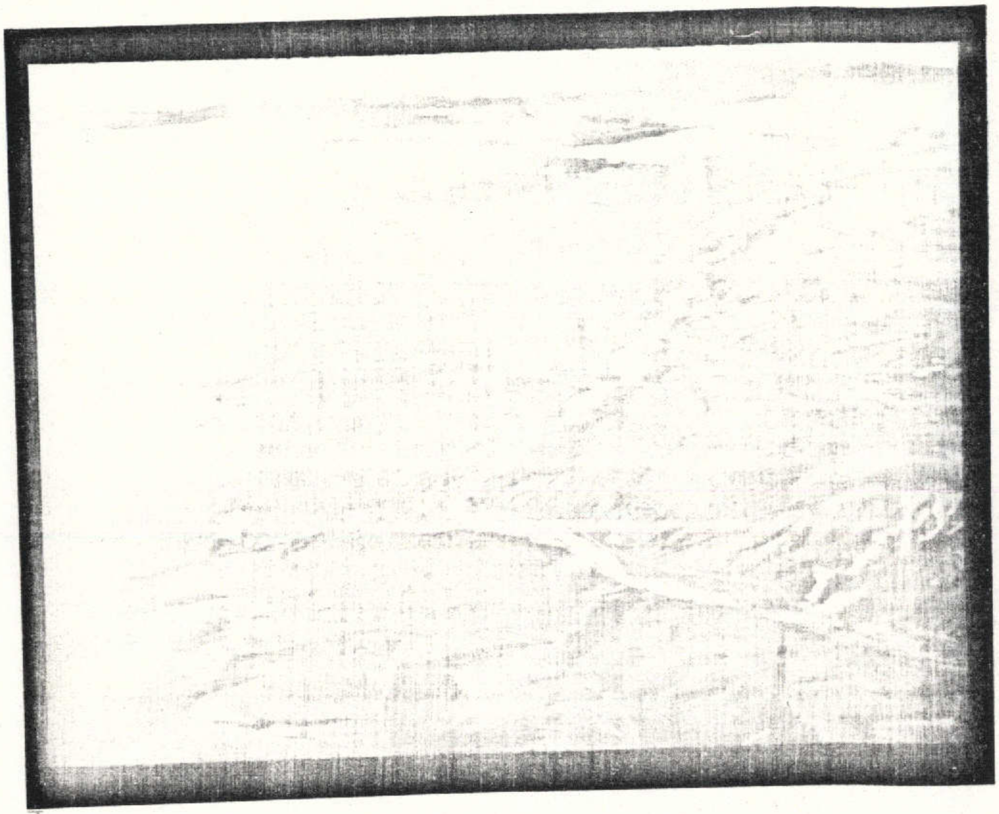


FIGURE 26. An oblique aerial view from south of Healy toward Nenana, Alaska just north of the Alaska Range (25 August 1972).

TABLE 1 . Variance, coefficient of variation, mean, mode, range and adequate training set size (Huntsburger, 1961) for ERTS-1 digital data picels (scene 1033-21011, 25 August 1972). Data are from six vegetation types and two water classes.

PARAMETERS	MSS BANDS 4	5	6	7
	(Cottonwood, 50 picels sampled)			
Variance	.690	.611	1.957	.972
Coefficient of variation	4.36	6.47	7.64	6.29
Mean intensity	15.8	9.4	25.6	15.4
Modal intensity	16	10	26,28	16
Intensity range	14-17	8-10	22-29	13-17
Adequate training set size ($d = 2, \alpha = .01$)	4	3	26	7
	(Deciduous forest - birch/aspen, 300 picels sampled)			
Variance	.849	.816	3.72	1.43
Coefficient of variation	1.76	8.96	10.87	6.48
Mean intensity	16.13	9.11	34.25	22.07
Modal intensity	16	9	35	22
Intensity range	14-18	7-11	30-40	18-27
Adequate training set size ($d = 2, \alpha = .01$)	5	5	92	14
	(Tall shrub, 100 picels sampled)			
Variance	0.720	0.763	1.912	1.369
Coefficient of variation	4.19	6.77	6.25	7.49
Mean intensity	17.23	11.27	30.59	18.27
Modal intensity	17	11	36	18
Intensity range	16-19	10-13	27-37	16-22
Adequate training set size ($d = 2, \alpha = .01$)	4	4	25	13
	(Muskeg or treeless bog, 275 picels)			
Variance	2.42	1.071	2.299	1.282
Coefficient of variation	12.97	8.89	8.61	8.65
Mean intensity	18.67	12.04	26.69	14.82
Modal intensity	17,18	12	28	15
Intensity range	15-19	9-13	20-31	11-18
Adequate training set size ($d = 2, \alpha = .01$)	39	8	35	11

TABLE 1 . (Cont.)

PARAMETERS	MSS BANDS 4	5	6	7
	(Mixed forest, birch-spruce, 300 picels)			
Variance	3.267	1.065	3.26	2.279
Coefficient of variation	20.22	10.87	15.78	20.158
Mean intensity	16.16	9.8	20.65	11.31
Modal intensity	17	10	19	10
Intensity range	14-18	7-12	14-30	7-19
Adequate training set size ($d = 2, \alpha = .01$)	71	8	71	35
	(Commercial spruce, 100 picels)			
Variance	.907	.977	2.530	1.700
Coefficient of variation	6.11	11.79	18.89	24.95
Mean intensity	14.84	8.29	13.40	6.82
Modal intensity	15	8	12	6,7
Intensity range	13-17	6-10	10-26	4-15
Adequate training set size ($d = 2, \alpha = .01$)	3	7	43	20
	(Silty water, 50 picels)			
Variance	.976	1.492	.888	.670
Coefficient of variation	3.23	5.28	3.89	10.46
Mean intensity	30.16	28.24	22.84	6.40
Modal intensity	30	29	23	6
Intensity range	28-32	25-31	21-25	5-8
Adequate training set size ($d = 2, \alpha = .01$)	7	15	6	3
	(Clear water, 15 picels)			
Variance	.704	1.060	2.052	1.309
Coefficient of variation	4.77	13.03	19.98	32.72
Mean intensity	14.73	8.13	10.27	4.0
Modal intensity	14,15	9	10,11	4,5
Intensity range	14-16	8.13	7-14	2-7
Adequate training set size ($d = 2, \alpha = .01$)	4	8	28	12

TABLE 2 . Frequency percentages of intensities in sampled picels in MSS digital data of three alder test sets and two deciduous forest test sets near Tustumena Lake, Alaska (scene 1390-20452, 17 August 1973).

INTENSITY LEVELS	TEST SETS				
	Alder 1	Alder 2	Alder 3	Deciduous 1	Deciduous 2
			BAND 4		
23	--	2.0	14.0	4.0	--
24	9.4	10.0	32.0	36.0	52
25	52.2	60.0	40.0	34.0	48
26	15.6	10.0	12.0	20.0	--
27	18.7	16.0	2.0	6.0	--
28	--	2.0	--	--	--
			BAND 5		
14	--	--	4.0	4.0	12
15	9.4	4.0	36.0	44.0	72
16	78.1	46.0	46.0	48.0	16
17	6.2	22.0	12.0	4.0	--
18	6.2	26.0	2.0	--	--
19	--	2.0	--	--	--
			BAND 6		
22	3.0	--	--	--	--
23	--	--	--	--	--
24	--	--	--	--	--
25	--	--	--	--	--
26	--	--	--	--	--
27	--	--	--	--	--
28	--	--	--	--	--
29	--	--	--	--	--
30	--	--	--	--	--
31	--	--	--	--	--
32	3.0	--	--	--	--
33	--	--	--	--	--
34	3.0	--	--	--	--
35	--	--	8.0	--	--
36	--	--	--	--	--
37	12.1	6.0	8.0	--	4
38	9.1	--	12.0	2.0	--
39	36.4	2.0	6.0	2.0	4
40	12.1	6.0	22.0	14.3	8
41	12.1	12.0	10.0	6.1	16
42	3.0	12.0	10.0	14.3	24
43	6.1	10.0	6.0	18.4	20
44	--	10.0	4.0	4.1	16
45	--	20.0	2.0	16.3	8

TABLE 2 . (Cont.)

INTENSITY LEVELS	Alder 1	Alder 2	Alder 3	Deciduous 1	Deciduous 2
			BAND 6 (Cont.)		
46	--	16.0	--	8.2	--
47	--	6.0	--	4.1	--
48	--	--	--	8.2	--
49	--	--	--	2.0	--
			BAND 7		
19	--	--	4.8	--	--
20	15.6	--	21.4	--	4
21	31.2	2.0	33.3	--	4
22	34.4	10.0	16.7	4.0	--
23	18.7	8.0	9.5	8.0	8
24	--	26.0	9.5	24.0	16
25	--	32.0	2.4	10.0	40
26	--	14.0	2.4	20.0	20
27	--	4.0	--	14.0	8
28	--	4.0	--	16.0	--
29	--	--	--	4.0	--

TABLE 3 . Listing of 59 potential users of ERTS data for resource management and development in Alaska.

USER	LOCATION
LOCAL	
Bristol Bay Borough	Naknek
Fairbanks North Star Borough	Fairbanks
Greater Anchorage Borough	Anchorage
Haines Borough	Haines
The City and Borough of Juneau	Juneau
Kenai Peninsula Borough	Soldotna
Ketchikan Gateway Borough	Ketchikan
The City and Borough of Sitka	Sitka
Matanuska Susitna Borough	Palmer
North Slope Borough	Barrow
STATE	
Office of the Governor-Division of Planning Research	Juneau
Department of Community and Regional Offices	
Division of Rural Development Assistance	Anchorage
Department of Economic Development	Juneau
Department of Environmental Conservation	Juneau
Office of Research & Academic Coordination	Fairbanks
Department of Fish and Game	State-wide
Department of Highways	State-wide (except Arctic)
Department of Natural Resources	Juneau
Division of Agriculture	Palmer
Division of Geological & Geophysical Surveys	Anchorage
Division of Lands	Anchorage
Minerals & Forestry Section	Anchorage
Water Resources Section	Anchorage
Division of Parks	Anchorage
University of Alaska	
Geophysical Institute	Fairbanks
Institute of Agricultural Sciences	Fairbanks & Palmer
Cooperative Extension Services	Fairbanks (state-wide)
FEDERAL	
Environmental Protection Agency	
Alaska Operation Office	Anchorage
Federal-State Land Use Planning Commission	Anchorage
United States Department of Agriculture	
Agricultural Research Service	Palmer
Agricultural Stabilization and Conservation Service	Anchorage
Soil Conservation Service	Anchorage
U.S. Forest Service	Juneau (and southcentral)
Institute of Northern Forestry	Fairbanks

TABLE 3. (Cont.)

USER	LOCATION
FEDERAL (Cont.)	
Pacific Northwest Forest & Range Experiment Station	Portland, Oregon
United States Department of Commerce	Anchorage
U.S. Weather Service	Anchorage
National Marine Fisheries Service	Juneau
United States Environmental Protection Agency	
Arctic Environmental Protection Agency	Fairbanks
United States Department of the Interior	
Alaskan Power Administration	Juneau
Bureau of Indian Affairs	Juneau
Bureau of Land Management	Anchorage
Bureau of Sport Fisheries & Wildlife	Anchorage
Geological Survey	Washington, D.C.
National Park Service	Anchorage
OTHERS	
Alaska Federation of Natives, Inc.	Anchorage
Regional Native Alaskan Corporations	
Ahtna Incorporated	Copper Center
Aleut Corporation	Anchorage
Arctic Slope Regional Corporation	Barrow
Bering Straits Native Corporation	Nome
Bristol Bay Native Corporations, Inc.	Dillingham
Calista Corporation	Anchorage
Chugach Natives, Inc.	Anchorage
Cook Inlet Region, Inc.	Anchorage
Doyon Limited	Fairbanks
Koniag, Inc.	Kodiak
Nana Regional Corporation	Kotzebue
Sealaska Corporation	Juneau

TABLE 4 . MSS signatures for six identifiable features in the ERTS-1 CCT data in the Homer vicinity of the Kenai Peninsula, Alaska (scene 1390-20452, 17 August 1973).

	INTENSITY RANGES IN REFINED SIGNATURES FOR FOUR BANDS			
FEATURE	4	5	6	7
Clear water	21-25	11-16	10-19	2-7
Silty water (Kachemak Bay)	20-26	10-14	6-9	0-3
Bare ground	25-32	18-26	14-25	4-11
Coniferous forest	20-26	13-15	20-28	10-17
Wetlands	23-34	16-31	23-39	13-29
Grass, alder and deciduous forest	21-28	13-20	40-60	12-34

TABLE 5 . MSS signatures for eight identifiable features in the ERTS-1 CCT data near Tustumena Lake, Alaska (scene 1390-20452, 17 August 1973).

FEATURE	INTENSITY RANGES IN REFINED SIGNATURES FOR FOUR MSS BANDS			
	4	5	6	7
Glacier	81-98	72-87	55-67	15-19
Clear water	20-29	12-19	11-23	3-9
Silty water (lake)	32-45	24-35	17-25	3-9
Alder & deciduous forest	23-28	14-16	34-49	19-29
Coniferous forest	23-28	13-19	20-27	10-17
Wetlands	24-29	17-21	28-36	12-22
Grass	23-28	17-21	37-54	18-30
Bare ground & rock	26-35	22-29	21-36	10-20

TABLE 6. Classification accuracies by MSS bands and overall as calculated from training set samples after signature refinement for six features distinguished in CCT data in the Homer, Alaska vicinity (scene 1390-20452, 17 August 1973).

	CLASSIFICATION ACCURACY PERCENTAGES MSS BANDS				OVERALL ACCURACIES	
FEATURE	4	5	6	7	Max.	Min.
Clear water	100	100	100	100	100	100
Silty water	100	100	100	100	100	100
Bare ground	100	100	100	100	100	100
Coniferous forest	100	94	100	100	94	94
Wetlands	100	96	87	99	87	83
Grass, alder and deciduous forest	100	100	89	100	89	89

TABLE 7. Classification accuracies by MSS bands and overall as calculated from training set samples after signature refinement for eight features distinguished in CCT data in the Tustumena Lake, Alaska vicinity (scene 1390-20452, 17 August 1973).

	CLASSIFICATION ACCURACY PERCENTAGES MSS BANDS				CALCULATED OVERALL	
FEATURE	4	5	6	7	Max.	Min.
Glacier	100	100	100	100	100	100
Clear water	100	100	100	100	100	100
Silty water	100	100	100	100	100	100
Alder-deciduous forest	100	82	100	100	82	82
Coniferous forest	100	100	84	98	84	82
Wetlands	100	79	78	100	78	62
Grass	100	77	94	100	77	72
Bare ground	100	91	100	100	91	91

TABLE 8 . MSS signatures for seven identifiable features in the ERTS-1 CCT data in the lower Kenai Peninsula vicinity (Alaska). These signatures were refined and combined from test sets taken from the Homer and Tustumena Lake localities.

	INTENSITY RANGES IN REFINED SIGNATURES FOR MSS BANDS			
FEATURE	4	5	6	7
Clear water	20-29	11-17	10-23	2-8
Silty water				
Bay	20-26	10-14	6-9	0-3
Lake	33-45	24-35	17-25	3-9
Bare ground	25-32	18-29	14-36	4-14
Coniferous forest	20-28	3-17	20-31	9-14
Wetlands	23-34	14-31	23-38	15-29
Grass, alder & deciduous forest	21-28	13-21	39-60	12-34

TABLE 9 . Classification accuracies by MSS bands and overall as calculated from refined and combined signatures derived for seven features at two test areas on the lower Kenai Peninsula, Alaska (scene 1390-20452, 17 August 1973).

FEATURE	NO. OF PICELS SAMPLED	CLASSIFICATION ACCURACY PERCENTAGE 4	5	6	7	OVERALL ACCURACY Max.	Min.
Clear water	80	100	95	100	99	95	94
Silty water							
Bay	150	100	100	100	100	100	100
Lake	150	91	100	100	100	100	91
Bare ground	155	94	100	100	83	83	78
Coniferous forest	225	100	96	100	88	88	84
Wetlands	315	100	100	84	92	84	77
Grass, alder and deciduous forest	556	100	100	86	100	86	86

TABLE 10. MSS signatures for 13 features identifiable in ERTS-1 CCT data from the Matanuska Valley, Alaska (scene 1390-20450, 17 August 1973).

	INTENSITY RANGES IN REFINED SIGNATURES FOR FOUR MSS BANDS			
FEATURE	4	5	6	7
Clear water	16-22	8-12	5-16	0-9
Silty water	26-38	16-33	13-27	4-10
Alpine tundra	20-29	17-22	44-57	21-37
Alder & grain fields	20-25	12-16	44-65	26-40
Scrubby spruce	19-23	11-14	19-28	11-22
Commercial spruce	17-25	12-26	17-23	8-10
Mixed forest	19-25	10-14	29-34	15-17
Deciduous forest	18-25	10-14	29-43	18-25
Bare ground	36-42	27-36	28-32	10-14
Rock				
North slope	17-25	13-31	8-20	2-7
South slope	25-34	22-30	22-34	11-16
Wetlands	19-25	15-21	24-34	10-21
Grass	21-28	15-27	35-43	14-25

TABLE 11. Classification accuracies by MSS bands and for all bands as calculated from training set samples after signature refinement for 13 features distinguished in CCT data from the Matanuska Valley, Alaska (scene 1390-20450, 17 August 1973).

	CLASSIFICATION ACCURACY PERCENTAGES MSS BANDS				OVERALL ACCURACY	
FEATURE	4	5	6	7	Max.	Min.
Clear water	100	98	98	100	98	96
Silty water	95	100	99	99	95	93
Tundra	100	94	84	100	84	79
Alder & grain fields	99	88	93	88	88	71
Scrubby spruce	100	89	86	96	86	73
Commercial spruce	100	100	96	92	92	88
Mixed forest	100	96	95	79	79	72
Deciduous forest	100	90	96	74	74	64
Bare ground	96	100	100	100	96	96
Rock						
North slope	90	82	92	88	82	60
South slope	100	100	100	100	100	100
Wetlands	100	88	87	100	87	77
Grass	100	91	80	100	80	73

TABLE 12. MSS signatures for eight features identifiable in ERTS-1 CCT data from the Susitna Valley, Alaska (scene 1033-21020, 25 August 1972).

FEATURE	INTENSITY RANGES IN REFINED SIGNATURES FOR FOUR MSS BANDS			
	4	5	6	7
Clear water	11-16	5-12	3-22	0-6
Silty water	20-25	11-19	13-21	4-9
Wetlands	14-19	10-14	15-34	9-27
Scrubby spruce	14-16	8-9	13-23	7-11
Birch (deciduous)	14-18	6-9	24-32	12-20
Mixed forest	13-16	6-9	19-23	12-14
Alder and/or grass	16-20	8-13	35-57	16-28
Tundra	17-22	10-14	41-56	29-36

TABLE 13. Classification accuracies by MSS bands and for all bands as calculated from training set samples after signature refinement for eight features distinguishable in CCT data from the Susitna Valley, Alaska (scene 1033-21020, 25 August 1972).

FEATURE	CLASSIFICATION ACCURACY PERCENTAGES MSS BANDS				OVERALL ACCURACY	
	4	5	6	7	Max.	Min.
Clear water	100	100	100	80	80	80
Silty water	96	100	100	100	96	96
Wetlands	100	87	81	100	81	70
Scrubby spruce	100	92	100	100	92	92
Birch (deciduous)	100	94	74	100	74	70
Mixed forest	100	100	96	100	96	96
Alder and/or grass	100	100	82	93	82	76
Tundra	100	100	100	83	83	83

TABLE 14. MSS signatures for eight features identifiable in ERTS-1 CCT data for the Bonanza Creek Forest vicinity near Fairbanks, Alaska (scene 1033-21011, 25 August 1972).

	INTENSITY RANGES IN REFINED SIGNATURES FOR FOUR MSS BANDS			
FEATURE	4	5	6	7
Clear water	14-16	6-9	7-14	0-5
Silty water	28-32	25-31	21-25	5-8
Commercial white spruce	13-17	6-10	11-15	6-15
Mixed forest & scrub	14-18	7-12	16-23	9-14
Treeless bog (wetlands)	15-21	11-15	24-31	11-16
Tall shrub	16-19	11-13	27-37	17-22
Deciduous (birch & aspen)	14-18	7-10	30-40	18-27
Cottonwood	14-17	8-10	22-29	15-17

TABLE 15. Classification accuracies by MSS bands and for all bands as calculated from training set samples after signature refinement for eight features distinguishable in CCT data from the Bonanza Creek vicinity, near Fairbanks, Alaska (scene 1033-21011, 25 August 1972).

	CLASSIFICATION ACCURACY PERCENTAGES MSS BANDS				OVERALL ACCURACY	
FEATURE	4	5	6	7	Max.	Min.
Clear water	100	100	100	93	93	93
Silty water	100	100	100	100	100	100
Commercial white spruce	100	100	85	89	85	76
Mixed forest & scrub	100	100	82	80	80	66
Treeless bog (wetlands)	99	96	94	93	93	87
Tall shrub	100	84	100	93	84	78
Deciduous forest (birch & aspen)	100	97	100	100	97	97
Cottonwood	100	100	100	82	82	82

TABLE 16. MSS classification accuracy percentages for similar features in scene 1033-21011 (Bonanza Creek area) and 1033-21020 (Susitna Valley area) using signatures derived from scene 1033-21011. Date of acquisition was 25 August 1972 for both scenes.

	OVERALL CLASSIFICATION ACCURACIES			
	1033-21020 Susitna Valley		1033-21011 Bonanza Creek	
FEATURE	Max.	Min.	Max.	Min.
Clear water	14	4	93	93
Silty water	0	0	100	100
Wetlands	44	14	92	86
Scrubby spruce	67	46	71	58
Deciduous forest	8	1	97	97
Average	24	11	90	86
Average (excluding silty water)	29	13	88	83

TABLE 17. MSS classification accuracy percentages for similar features in scene 1033-21020 (Susitna Valley area) and 1033-21011 (Bonanza Creek area) using signatures derived from scene 1033-21020. Date of acquisition was 25 August 1972 for both scenes.

	OVERALL CLASSIFICATION ACCURACIES			
	1033-21020 Susitna Valley		1033-21011 Bonanza Creek	
FEATURE	Max.	Min.	Max.	Min.
Clear water	80	80	93	93
Silty water	96	96	0	0
Wetlands	81	70	100	100
Scrubby spruce	92	92	7	1
Deciduous forest	74	70	10	1
Alder	94	90	3	3
Average	86	83	36	33
Average (excluding silty water)	84	80	43	40

TABLE 18. Listing of costs for producing color-coded, geometrically-corrected vegetation maps from ERTS-1 CCT data, given ground truth and CCT data for a 512 x 512 picel area. (May 1974 prices)

ITEM	COST ($)
Preparing 512 x 512 from NASA CCT (IBM 360/40)	15-30
Listing intensity data (IBM 360/40)	12
Signature extraction and refinement (Zoom Transfer Scope)	400-575
Classifying data (IBM 360/40)	45
Color coding files (IBM 360/40)	45
Geometric correction (IBM 360/40)	45
Color printing (Dicomed D-47)	60
Color separation (contract)	100-
Total cost	722-912
Cost/mi^2	1.58-1.99

TABLE 19. Listing of costs for producing false-color, geometrically-corrected digital prints from ERTS-1 CCT data for a 512 x 512 picel area. (May 1974 prices)

ITEM	COST ($)
Preparing 512 x 512 from NASA CCT (IBM 360/40)	15-30
Color spreading 3 file (IBM 360/40)	45
Geometric correction (IBM 360/40)	45
Color printing (Dicomed D-47)	60
Color separation (contract)	100
Total cost	265-280
Cost/mi^2	0.58-0.61

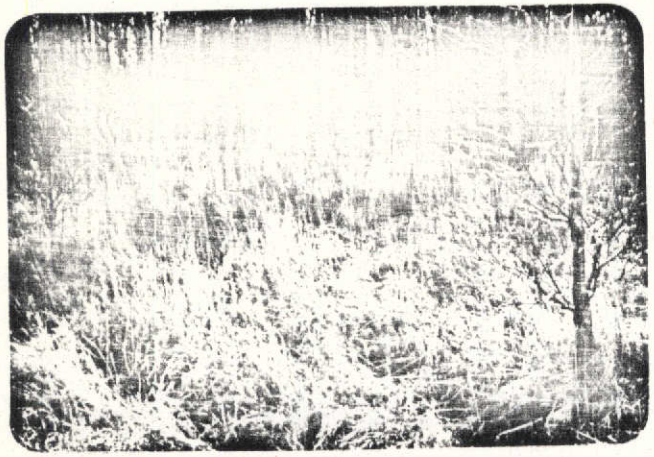
APPENDIX A

Two photopoint series of grass (A_1) and mixed forest (A_2) vegetation types acquired at monthly intervals near Palmer, Alaska, during the April 1973 through March 1974 period. These photos show the rapidity of change in phenological aspects of Alaskan vegetation and the relative brevity of the growing period. *'s mark the photos which were taken near to the times when useable ERTS-1 imagery was also secured.

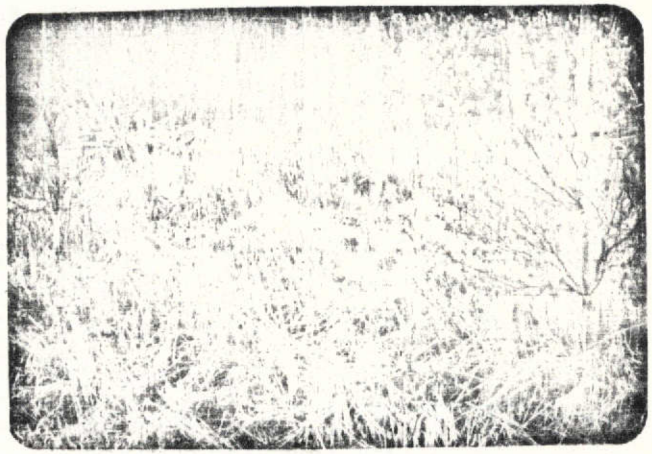
The following table depicts the dominant vegetation shown in the photographs of the grass type, Appendix A_1 and the mixed forest type of Appendix A_2.

	OVERSTORY	UNDERSTORY
Appendix A_1 Grass Type	Paper birch Betula papyrifera Marsh.	Grass: Bluejoint (Calamagrostis canadensis (Michx.) Beauv. Forb: Fireweed (Epilobium angustifolium L.
Appendix A_2 Mixed Forest type	Paper birch Betula papyrifera Marsh, White spruce Picea glauca (Moench) Voss	Shrub: High bush cranberry Viburnum edule (Michx.) Raf. American red currant Ribes triste Pall.

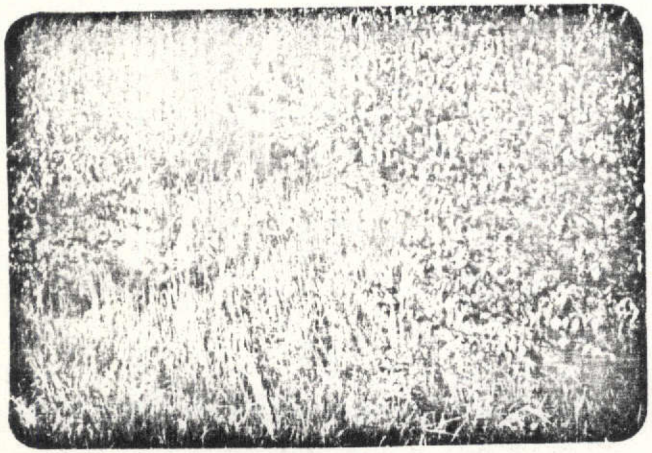
APPENDIX A_1 PHENOLOGY GRASS TYPE



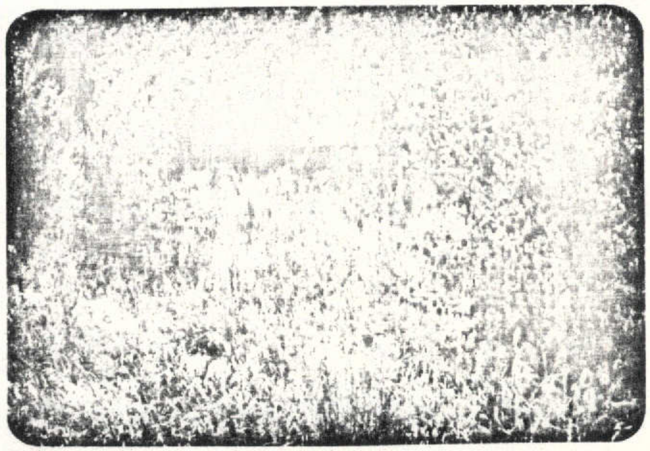
April 16, 1973



May 15, 1973

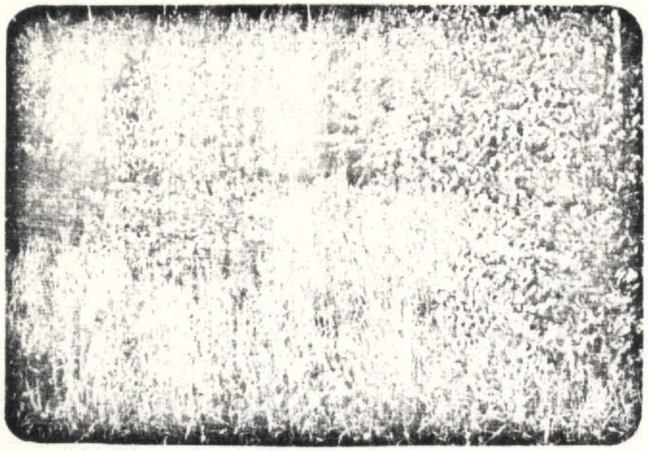


June 11, 1973

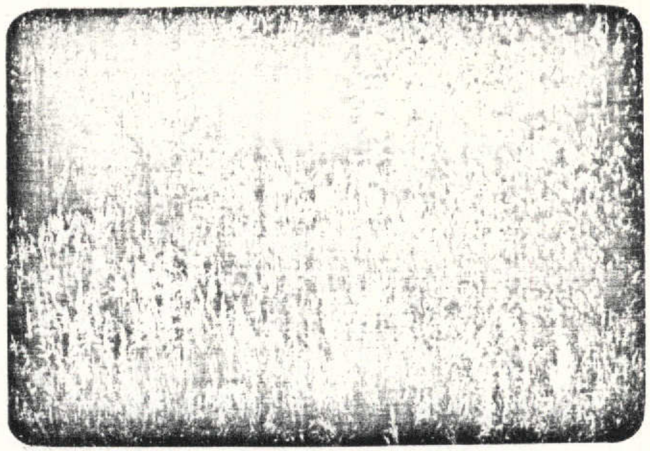


July 16, 1973

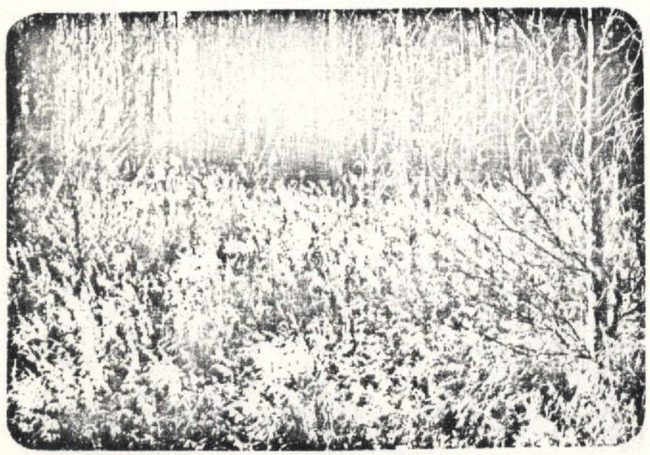
APPENDIX A_1 PHENOLOGY GRASS TYPE



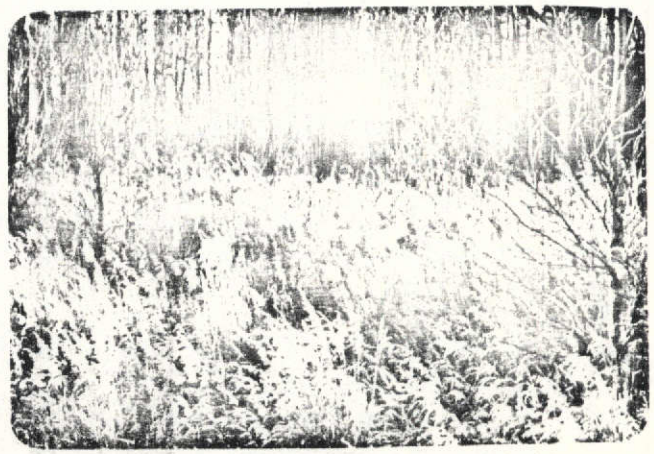
August 13, 1973*



September 18, 1973*

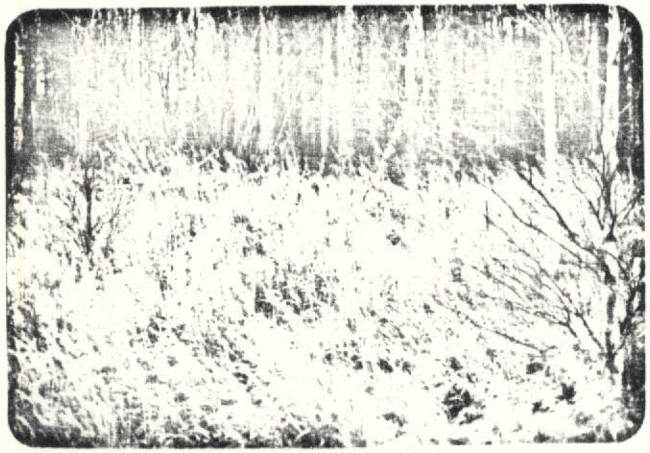


October 16, 1973



November 17, 1973

APPENDIX A_1 PHENOLOGY GRASS TYPE



December 17, 1973

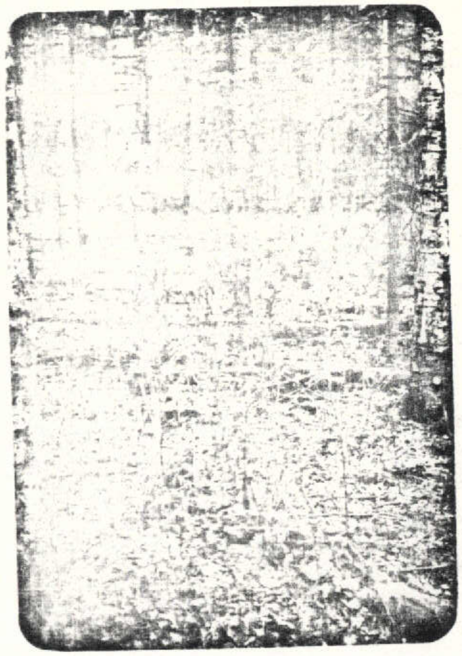
January 14, 1974

February 18, 1974

March 18, 1974

APPENDIX A_2 PHENOLOGY MIXED FOREST TYPE

April 16, 1973



May 15, 1973

June 11, 1973

July 16, 1973

APPENDIX A_2 PHENOLOGY MIXED FOREST TYPE

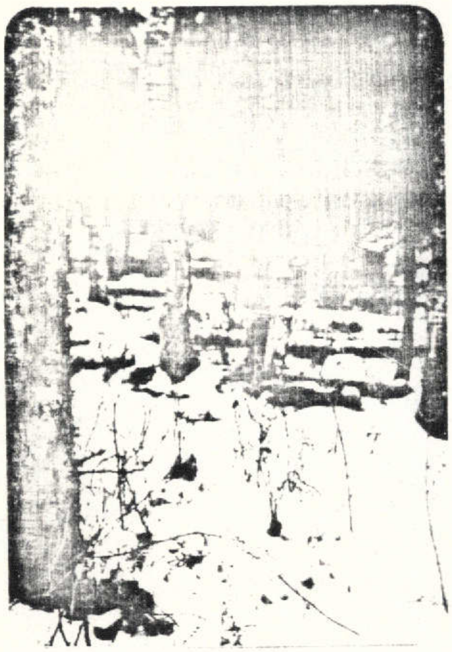
August 13, 1973*

September 18, 1973*

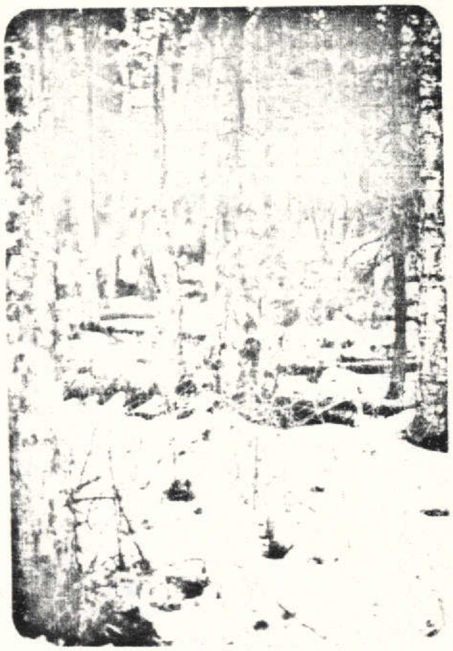
October 16, 1973

November 17, 1973

APPENDIX A_2 PHENOLOGY MIXED FOREST TYPE

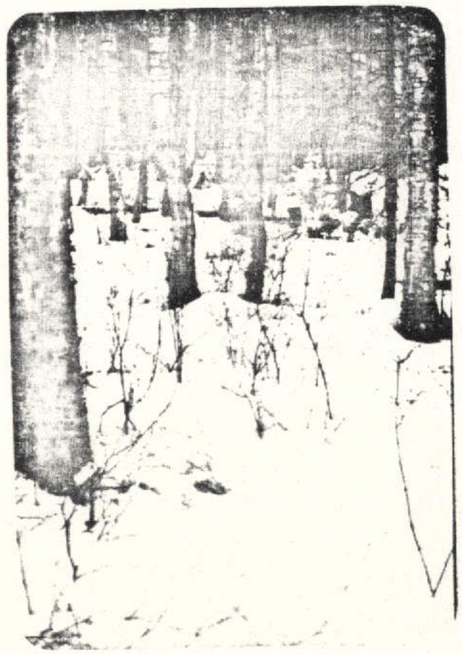


December 17, 1974



January 14, 1974

February 18, 1974



March 18, 1974

APPENDIX B

A geometrically-corrected false-color image for approximately 500 square miles in the Prudhoe Bay area of Alaska. The road systems of the oil field can be seen paralleling the Sagavanirktok River on the right hand side of the image. Note the lineament of the lakes which is 90° to the prevailing wind pattern. Produced from MSS CCT data bands 4, 5 and 7 (scene 1326-21284). (Image generated via the Dicomed D-47 digital printer.)